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NUMBER OF GENERATIONS OF *LYGUS HESPERUS* KNT. AND *L. ELISUS* VAN D. IN ALBERTA[1]

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R. W. SALT[2]

Dominion Entomological Laboratory, Lethbridge, Alberta

Several papers dealing with the legume bugs, *Lygus hesperus* Knt. and *L. elisus* Van D., have recently appeared in entomological literature. In addition there are some previous articles concerning *Lygus pratensis* L. which should properly include *L. hesperus* and *L. elisus*, due to a failure to distinguish specific differences. The two first-mentioned species are so intermingled in many areas and have such similar habits that for most practical purposes they may be studied as a single species, and several workers have done so. In view of the considerable amount of study which has been devoted to these pests it is remarkable that a particular error should crop up again and again, not merely by quotation but in independent research. Reference is made to the number of generations of *Lygus* per year, particularly in the northwest United States.

Several writers state that they have endeavoured to rear *Lygus* through successive generations, but the best that seems to have been accomplished so far is one complete generation. Most of the data are composite records from the rearing of the various stages. From these the life cycle has been variously reported as requiring 20 to 30 days under favourable conditions, but running as high as 46 days. Some authors have divided this period into the length of the active season, getting from 3 to 7 generations (1, 2, 4). Although this may seem a logical method of determining the number of generations, it proves to be a very inaccurate one. It fails to take into consideration the fact that the time required for different individuals to complete a generation varies in accordance with a number of complex ecological and nutritional factors, and any attempt to strike an average for use in calculations such as the above only increases the error. As no one has yet been successful in rearing successive generations of *Lygus elisus* or *L. hesperus*, the next best resort is to determine the number of generations from fluctuations in the numbers of each stage of the insect, in a specific natural environment and throughout a complete season.

During the summer of 1938 the writer made such a study of *Lygus hesperus* and *L. elisus* by making periodic collections in an alfalfa seed field located on the Dominion Experimental Farm at Lethbridge, Alberta. The field remained uncut during the entire period. Collections were taken approximately once a week until the first appearance of nymphs and twice a week thereafter. During the early part of the season, when adults were scarce, 1,000 sweeps with a 14-inch net were taken as a unit collection, but

[1] Contribution No. 2357, Division of Entomology, Science Service, Department of Agriculture Ottawa, Canada.

[2] Agricultural Scientist.

later the units were cut to 100 sweeps. The results are contained in Figure 1, each instar being shown separately. Taking into consideration the variation in collecting conditions during the summer, and the fact that two species are involved, the population curves shown in the figure are quite uniform.

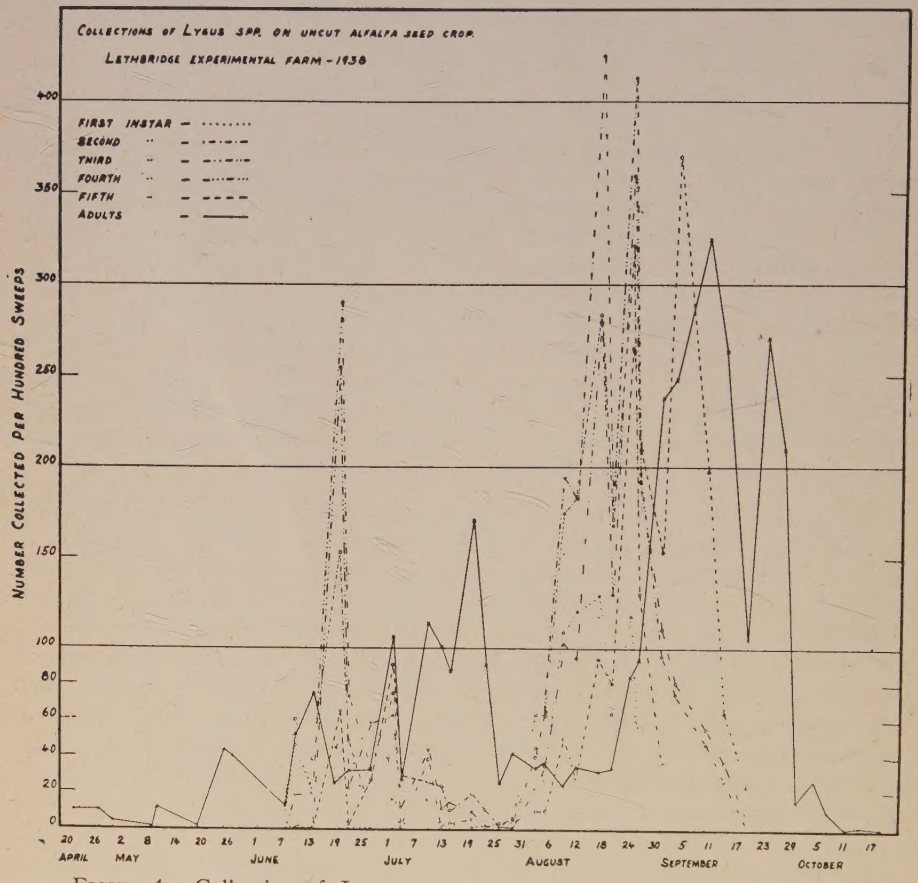

FIGURE 1. Collection of *Lygus* spp. on uncut alfalfa seed crop at Dominion Experimental Farm, Lethbridge, Alberta, 1936.

In order to determine the number of generations it is necessary to consider the various curves one at a time. The adult curve stands out distinctly from those of the nymphal instars and shows a peak during the middle of July following a previous peak in the nymphal population. A secondary peak on September 23, following a drop on September 19, could not possibly be interpreted as another generation as the time is much too short, especially so late in the season. In addition, the low nymphal population at that time precludes such an idea, and if further proof be needed it is found in the fact that egg development in the adult females ceases before that date. Turning next to the five nymphal instars, if the population curve of each is carefully followed in the figure, it will be seen that

each instar follows in point of time the preceding instar. This is especially clear in the part of the curves subsequent to August 1, where there is decidedly but one generation. The earlier build-up of nymphs during June is not so clear, but that only one generation is involved can be easily shown as follows. The second, third and fourth instars were at a peak on June 20. A secondary peak on July 2 not only leaves insufficient time for another complete generation to have developed but it is composed of later stages than the first peak, namely, fourth- and fifth-instar nymphs and adults. The secondary variations shown in the curves are due mainly to differences in weather conditions, but even these are not sufficient to obliterate proof of the existence of only two generations of *Lygus* in this area. It is entirely possible, of course, that an occasional individual developed sufficiently in advance of the remainder to go through three or even more generations, but the low ebb of nymphs on and around July 26 makes it reasonably certain that the number of such individuals was minute.

More than two generations may, of course, occur farther south. However, Shull (3) published data similar to that given in the figure, listing the numbers of *Lygus* collected in an alfalfa field and a clover field in southern Idaho from April 27 to August 18, 1931. Three sets of figures are listed for each field—the number of nymphs, the numbers of adults, and a total of the two. The totals are also presented graphically. On the basis of these data Shull makes the statement, "There are four generations in southern Idaho each year as shown by the counts from alfalfa and clover sweepings in 1931 (Table XVI, Fig. 1, D)". A glance at the table shows two definite peaks of nymphal abundance, each indicating a clear-cut generation. The author, however, adds the nymphal figures to the adult figures and gets four peaks of abundance, concluding that there are four generations per year. Strangely enough, his first generation reached a peak on May 15, although the first nymphs of the season did not appear until May 21. Shull's data, therefore, give evidence of only two generations between April 27 and August 18, 1931. It is unfortunate that he did not carry his observations to a later date, for there may have been time for a third generation subsequent to August 18. It can be definitely said, however, that on the basis of Shull's data there are at least two, possibly three, but not four generations of *Lygus* in southern Idaho.

DISCUSSION

Two errors concerning the determination of the number of generations undergone by insects during a year are pointed out. Although specifically referring to *Lygus hesperus* and *L. elisus*, these comments undoubtedly apply in many other cases:

1. The practice of calculating the number of generations per year from the length of the total season and the length of one generation is inaccurate.

Variations in individual insects, combined with variations in environment throughout a field and throughout a season, do not allow the use of such simplified mathematics based on averages.

2. In determining the number of generations per year from population curves, each stage and instar should be studied as a separate entity. The bulking of population figures of various stages and instars leads to inaccurate conclusions.

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A CONTRIBUTION TO THE KNOWLEDGE OF THE ACRIDIDAE OF ALBERTA[1]

R. M. WHITE[2] AND P. J. G. ROCK[3]

Dominion Entomological Laboratory, Lethbridge, Alberta

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Since the publication of *Orthoptera of Alberta*, by Morgan Hebard in 1930 many new distributional records of Acrididae have been obtained in this province. During the current grasshopper outbreak, which started in 1930, the authors, while making surveys of grasshopper abundance, have covered much of the agricultural area of the province. Considerable collecting of all species has been done, particularly since 1936, and it has been possible to add materially to past records. The northwestern limits of distribution of a number of plains species and the southeastern limits of distribution of a number of boreal species are more clearly defined than they were in 1930. Few additional records have been secured from many of the less accessible and non-agricultural areas and, though occasional collecting was done in the mountainous regions, the information regarding the forms inhabiting those areas is still far from complete. The distribution of the spring forms of acridids is better understood than was the case in 1930 but it still leaves much to be desired. Supplementary notes will have to be published as more data are assembled.

Since material was collected from over 2500 localities, the authors, in order to avoid cumbersome lists of locations, have divided the province into ecological areas following the method used by Strickland (7), see Figure 1. Some alterations have been made in the boundaries, and the numbering of Strickland's ecological areas to make them more applicable to orthopteriod distribution.

DESCRIPTION OF ECOLOGICAL AREAS

A. TRANSITION ZONE

1. Southern Prairie (Milk River Valley and ridge to the south)
   Vegetation:—Short grass; *Artemesia* and greasewood.
   Soil:—Brown.
   Remarks:—This area is a northern extension of the Upper Sonoran or Upper Austral Zone. It is devoted chiefly to ranching except in the district around Coutts where there is considerable farming.
2. Cypress Hills
   Vegetation:—About 50% forested—lodge-pole pine, spruce and poplar, long grass.
   Elevation:—Up to 4500 feet. Summit of hills never glaciated.
   Soil:—Very dark brown to black.
   Remarks:—Flora and fauna quite similar to Waterton Lakes (16) area.

[1] Contribution No. 2349, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Assistant Entomologist.
[3] Agricultural Assistant.

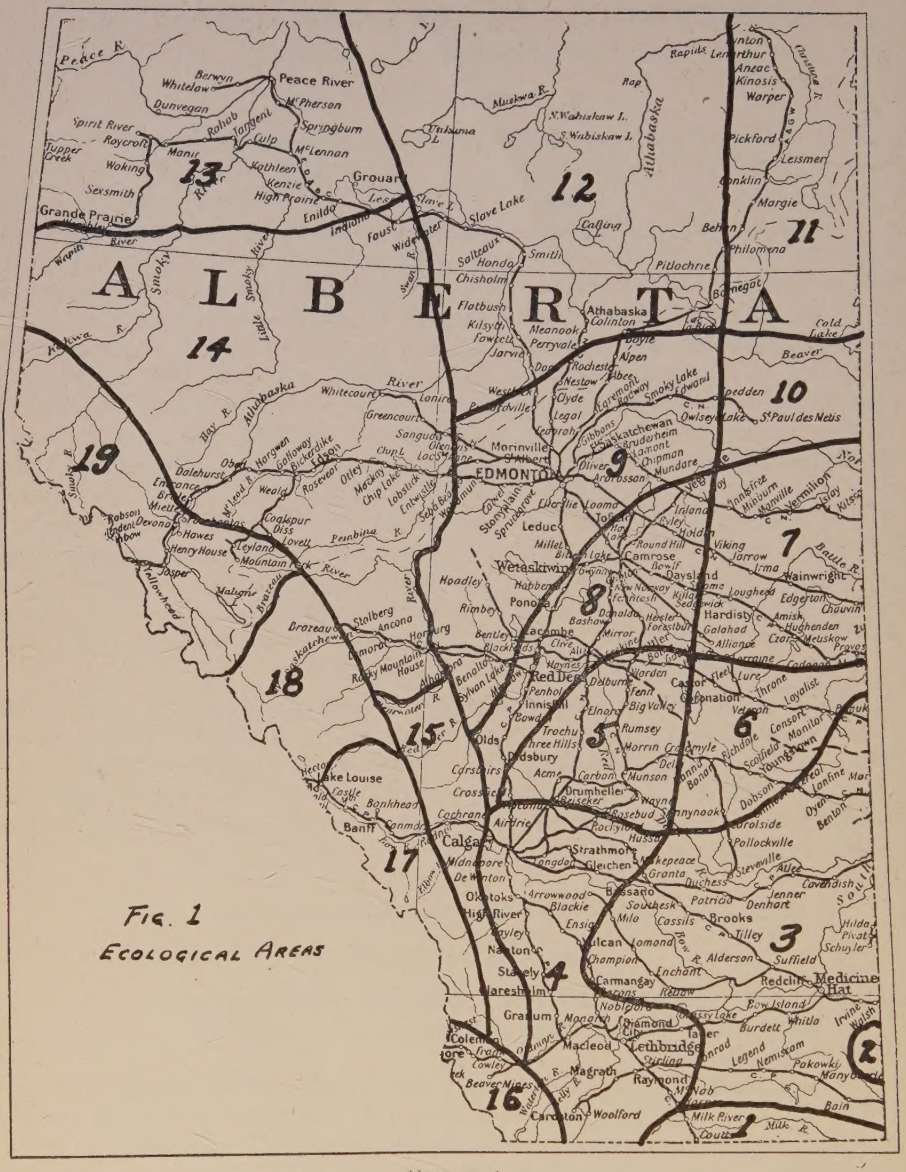


FIG. 1
ECOLOGICAL AREAS

FIGURE 1

3. Southern Prairie (Manyberries-Bassano-Altario)

Vegetation:—Short grass. Some poplars and willows in river bottoms. Cactus and sage in drier locations. Irrigated areas around Brooks which support a variety of crops, chiefly grain; much abandoned land, that more recently abandoned grown up to Russian thistle and tumbling mustard. Considerable areas of blow-out soil. Eroded areas adjacent to river bottoms. Some alkali sloughs and lakes.

Soil:—Brown.

4. Southern Prairie and Southern Extension of Northern Prairie (Woolford-Calgary-Hussar)
   Vegetation:—Short to intermediate grass, occasional groves of willow and poplars. Crops, chiefly wheat.
   Soil:—Brown to dark brown. Some eroded land along rivers; some alkali sloughs.
5. Northern Prairie, West (Crossfield-Halkirk)
   Vegetation:—Intermediate grass; poplars, willows. Crops chiefly wheat.
   Soil:—Dark brown, ranging from loam to very heavy clay or "gumbo."
6. Northern Extension of Southern Prairie (Sunnynook-Castor)
   Vegetation:—Short to medium tall grass; a few trees along creeks and some alkali sloughs.
   Soil:—Brown.
   Remarks:—Marginal area for grain growing; large amount of abandoned land.

B. Intermediate Between Transition and Canadian Zones

7. Parkland, East (Provost-Vermilion)
   Vegetation:—Short to long grass. About 30% wooded with aspen poplar and willow groves. Crops, grain and hay.
   Soil:—Dark brown to black.
8. Parkland, West (Didsbury-Vegreville)
   Vegetation:—Originally about 50% wooded with aspen and willows, area now 75% cleared. Crops, grain and hay.
   Soil:—Black.

C. Canadian Zone

9. Poplar, West (Rocky Mountain House-Lac la Biche)
   Vegetation:—Long grass. Originally balsam poplar, aspen, willow and some spruce; less than 50% cleared. Crops, mostly oats.
   Soil:—Black to grey-wooded in North.
10. Poplar, East (St. Paul des Metis)
    Vegetation:—Fall grass. Originally balsam poplar, aspen, willow with considerable local stands of spruce and pine; about 40% cleared. Crops, wheat and oats.
    Soil:—Black, some muskeg.
11. Mixed Forest with Eastern and Sub-arctic Intrusions
    Vegetation:—Largely forested with aspen, balsam poplar, spruce, jack pine, balsam fir, tamarack, willow, birch and alder.
    Soil:—Grey-wooded, with extensive areas of sand.
    Remarks:—No collections of Orthoptera have been made in this area.
12. Mixed Forest, with Cordilleran (Rocky Mountain) Intrusions
    Vegetation:—Similar to No. 11. Many lakes and large areas of muskeg. A little cultivation in the south. Crops, chiefly oats.
    Soil:—Gray-wooded.

13. Mixed Forest and Parkland (Peace River District)
    Vegetation:—Large areas of forest interspersed with long grass open plains. Crops, chiefly grain.
    Soil:—About 10-15% black loam, remainder gray-wooded with some muskeg.

D. Foothills Zone

14. Foothills, Northern (Rocky Mountain House-Grand Prairie)
    Vegetation:—Intermediate between that of Rocky Mountains and the mixed forest of northern Alberta. Much of this area is incompletely surveyed. In the western half some grain is produced.
    Soil:—Gray-wooded; believed to be quite variable.
15. Foothills, Southern (Cowley to Rocky Mountain House)
    Vegetation:—Aspen, spruce, lodge-pole pine, willow with mixed grasses and open prairie to southward.
    Soil:—Gray-wooded in northern portion, dark brown to black in south.
    Remarks:—This area is probably the most uniform of all areas.

E. Mountain Zone

According to Strickland (7) "Vegetation:—This naturally varies greatly with the altitude of the montane, submontane, subalpine and alpine territory, also with topography, rock and soil. Montane territory is dominated by lodge-pole pine and white spruce. Douglas fir is locally abundant. Subalpine territory is characterized by Engelmann spruce, alpine fir, and other conifers, as well as by mountain heaths.

"From Area 18 to Area 21 (Area 16 to Area 19 in Fig. No. 1) there is a gradual and irregular replacement of southern and western species by certain boreal and arctic species."

16. Southern Rocky Mountains (Waterton-Blairmore)
    Vegetation:—"Strong intrusions of southern and western species. These extend to about the northern limits of the area."
    Soil:—The composition of the mountains in this area changes from largely igneous rock in the south to a high percentage of limestone in the north.
17. Central Rocky Mountains (Crow's Nest Pass-Lake Louise)
    Vegetation:—Typical for that of Area 16 with a few southern and arctic intrusions.
    Soil:—Variable in texture; all gray-wooded.
18. North Central Rocky Mountains (Banff Park, North)
    Vegetation:—Similar to that of Area No. 17. Among the grasses are several which appear to be typical of the Labrador flora.
    Soil:—Similar to that of Area No. 17.
    Remarks:—Little collecting of Orthoptera has been done in this area.
19. North Rocky Mountains (Jasper National Park)
    Vegetation:—As in Nos. 17 and 18 but with strong intrusions of arctic and boreal species.
    Soil:—As in No. 18.

DISTRIBUTION OF SPECIES

Each species is recorded in the following manner:

1. The numbers of the various ecological areas from which it has been taken.

2. A list of the localities from which it has been previously recorded in the various publications by Hebard or by Tinkham (8).

3. The names of the towns comprising the north or northwestern limits of distribution in the cases of the plains species, or southeastern limits in the cases of the boreal species.

4. Notes of interest in connection with the species.

For example:

Ageneotettix deorum deorum (Scud.)

1, 3, 4, 5, 6, 7. Previous records are from Lethbridge, Coaldale, Taber, Medicine Hat, Steveville and Comrey. Alliance and Carstairs are the northern limits of distribution.

This species is fairly common in the southern portion of the province but is relatively scarce towards the northern limits of its distribution.

The numbers 1, 3, 4, 5, 6, 7, refer to the ecological areas from which these species has been collected. The remainder of the data are self-explanatory.

Mermeria maculipennis macclungi Rehn.

New record.

Reared from fifth instar nymphs collected at the mouth of the Lost River and in Blacktail Coulee at Onefour, one mile north of the Montana boundary. Five nymphs collected July 16, 1940. One adult emerged Aug. 1, 1940 (White & Rock). The species was present in clumps of *Calamovilfa longifolia* (Hook) in small numbers in sheltered places on the north banks of coulees.

Previous northern records from Montana are: Brinkman, July 25, 1935 (Shotwell and White), Billings, July 30, 1910 and Columbus, Sept. 1, 1924 (N. Criddle).

Acrolophitus hirtipes (Say)

1, 2, 3, 4. Previous records are Medicine Hat, Lethbridge and Macleod. Gleichen is the most northerly record.

This rather uncommon species is usually found on the brows of the banks of river valleys.

Opeia obscura (Scud.)

1, 2. This species was first taken by Tinkham at the Higdon Ranch, Comrey, in 1938. Further series were secured from Coutts, the Milk River Valley and Manyberries in 1939 and 1940.

A specimen in the collection was taken at Willow Bunch, Sask., Sept. 25, 1931 (G. F. Manson).

Amphitornus coloradus (Thos.)

1 to 9. Previous records are Manyberries, Walsh, Steveville, Taber, Minda, Comrey and Lethbridge. (Minda was formerly a post office 5 miles N.E. of Manyberries.)

Northern records are Rochester and Wainwright.

This species is one of our most common range grasshoppers in southern Alberta. Towards its northern limits of distribution in the park belt it is quite scarce and is confined largely to grassy knolls.

Eritettix simplex tricarinatus (Thos.)

1. New record for Canada (Det. A. B. Gurney.)

This insect was taken in the Blacktail Coulee, at Onefour, July 15, 1940 (White & Rock). Hebard (2) gives Bozeman, Mont., as the nearest point at which this species was taken previously.

Phlibostroma quadrimaculatum (Thos.)

1, 3, 4, 5, 6 and 17. Previous records are from Banff, Calgary, Lethbridge, Bow Island, Medicine Hat, Walsh and Comrey.

Banff and Wayne are northern records.

Cordillacris occipitalis cinerea (Bruner)

1, 3 to 7. Previous records are Lethbridge, Manyberries and Comrey. Ribstone, Amisk, Scapa and Morrin are northwestern records of distribution.

This species is confined largely to sand areas, river valleys and eroded areas.

Cordillacris crenulata (Bruner)

1. New record for Canada. (Det. by R. M. White, by comparison with specimen from Wyoming det. by Morgan Hebard.)

Taken in the valley of the Lost River, Onefour, July 15, 1941 (White).

Orphulella pelidna (Burm.)

1, 3 and 6. This species was first collected by Criddle at Orion in 1924 and reported by Hebard (6). It was again reported from Irvine, Cereal and Finnegan by Gurney (9). The writers have taken it, from a number of localities, in coarse grass at the edges of marshes and alkaline sloughs and springs. The species is quite localized in its habitat in Alberta.

Northwestern records are Coutts, Dorothy and Cereal.

Chloealtis conspersa Harris

1, 3, 4, 5, 7, 8, 9, 12, 13, 14, 16 and 17. Previous records are Crow's Nest Pass, Frank, Banff, Athabasca and Comrey.

The southern limits of distribution of this species are Cowley and Comrey. The latter record is only ten miles from the Montana border so the species should be present in the Sweet Grass Hills of that state.

A fully macropterous female was collected along the Smoky River near Debolt in Area 13 in 1938, while a male was taken at Fenn in 1939 (Rock).

Neopodismopsis abdominalis (Thos.)

2, 4 to 19. Previous records are Coleman, Fort Macleod, Lethbridge, Banff, Nordegg, Greencourt, Cold Lake, Cypress, Blairmore and Crow's Nest Pass.

This handsome species is quite widely distributed in the park belt. In the prairie section it is quite scarce and is usually confined to patches of *Symphoricarpos* along river bottoms or on hillsides.

Chorthippus longicornis (Latr.)

1 to 19, except 11. This species has previously been recorded from Coleman, Macleod, Fort Macleod, Blairmore, Cypress, Comrey, Banff, Tofield, Edmonton, Ponoka, Red Deer, Greencourt, Halcourt, Cold Lake and Grande Prairie.

It is the most common of the species that occur in the park belt. In the plains section it is confined largely to marshes or to clumps of *Symphoricarpos* along streams or in wooded hills.

The series shows a wide variation in the length of the organs of flight. Females range from brachypterous to macropterous. A few fully macropterous males are present but in the majority the tegmina extend only to the tip of the supra-anal plate or just beyond the tip of the abdomen at most.

Aeropedellus clavatus (Thos.)

1 to 19, except 11 and 18. Previous records are from Banff, Jasper, Fort Macleod, Lethbridge, Chin, Manyberries, Medicine Hat, Cypress and Comrey.

This species has probably the widest distribution of the acridids that occur in Alberta.

Bruneria brunnea (Thos.)

1 to 8, 10, 15, 16, 17, 19. Previous records are from Cypress, Comrey, Chin, Lethbridge, Kipp, Fort Macleod, Pincher, Coleman, Frank, Blairmore, Crow's Nest Pass, Banff and Jasper.

Jasper, Delbourne, Heisler and Myrnam are the northern records.

This is a moderately common species in areas of short dry grass.

Psoloessa delicatula delicatula Scud.

1, 3 to 7, 15 and 16. Previous records are Calgary, Macleod, Lethbridge and Comrey.

Lavoy is the most northern record. The species is a spring form and its distribution probably extends considerably north and west of this point.

Adults of this species are fairly common from May until July.

Ageneotettix deorum deorum (Scud.)

1, 3 to 7. Previous records are from Steveville, Lethbridge, Chin, Taber, Medicine Hat and Comrey.

Alliance and Carstairs are northern points of distribution.

This species is fairly common in the southern portions of the province but is relatively scarce towards the northern limits of its distribution.

Drepanopterna femoratum (Scud.)

1. This species was first collected at the Higdon Ranch, Comrey, by Tinkham in 1938. Further series were secured in 1939 and 1940 along the Milk and Lost rivers from Onefour to the Higdon Ranch (about 12 miles west of Comrey).

Aulocara elliotti (Thos.)

1 to 8, 15 and 16. Previous records are from Steveville, Macleod, Lethbridge, Chin, Taber, Manyberries, Comrey and Medicine Hat.

Cochrane, Alix and Lavoy are northwestern records.

This is economically the most important species of the grasshoppers affecting the ranges in Alberta.

Stethophyma gracile (Scud.)

8, 9, 10, 12, 13, 14. Previous records are Cold Lake, Edmonton, Greencourt and Coronado.

Dundre, Delbourne and Strome are southern records.

This insect is quite local in its distribution as it is nearly always found in sedgy meadows, grassy swamps and occasionally in muskegs.

Stethophyma lineatum (Scud.)

7, 8, 9, 10, 13, 14. Cold Lake is the only previous record. Czar and Sundre are the southernmost records of the discontinuous distribution of this species.

This insect is usually found in the same habitat and in company with *S. gracile.*

Arphia conspersa Scud.

1 to 19, except 11. Previous records are Lethbridge, Calgary, Banff, Nordegg, Cold Lake, Wabamun, Grande Prairie, Peace River and Fort Vermilion.

This is the most common, and widely distributed spring form.

The wing discs are pink in all specimens except those from the vicinity of Jasper. There, only specimens with yellow to orange-yellow wings have been found. Yellow-winged specimens have been reported, by Hebard, from Banff, Nordegg and Wabamun.

Four females are light brown in colour.

Arphia pseudonietana pseudonietana (Thos.)

1, 3 to 9, and 17. Previously recorded from Banff, Calgary, Gull Lake, Medicine Hat, Walsh and Comrey.

Gull Lake and McLaughlin are northern records.

This handsome species is present in small numbers in the grasslands of Alberta. In two males and five females the disc of the pronotum, and the caudal portion of the occiput, is buffy, in sharp contrast to the darker parts of the insect.

Chortophaga viridifasciata (De Geer)

4 and 5. Previous record—Lethbridge.

Erskine is the most northern distributional record.

This spring form, which is frequently found in sandy soil in the river bottoms, appears to be quite localized in its distribution. It has been taken from only sixteen localities in these two areas.

Of the 34 males, 33 are brown and one is green with brown tegmina: of the 23 females, 20 are green, 2 are brown and one is green with brown tegmina. All specimens have yellow wing discs.

Encoptolophus sordidus costalis (Scud.)

1, 3 to 10, 15 and 16. Previous records are Edmonton, Steveville, Orkney, Lethbridge, Welling, New Dayton, Comrey and Walsh.

Northern records are Morinville and Heinsburg.

This widely distributed species occurs in about the same numbers as *Amphitornus coloradus* (Thos.)

Camnula pellucida (Scud.)

1 to 19. Previously recorded from a number of localities of which the most northerly are Edmonton and Cold Lake.

This is the most widely distributed and the second most abundant of the destructive species of grasshoppers in the province.

Pardalophora apiculata (Harris)

4, 7, 8, 9, 13, 14, 15. Previous records are Grande Prairie, Edmonton, Wabamun, Red Deer and Calgary.

Southern records are Millarville, Red Deer and Hughendon.

This insect, which is found in small colonies, matures in May and June. It frequently occurs in sandy areas in the park belt, particularly where *Eleagnus* is present.

Xanthippus corallipes latefasciatus (Scud.)

1, 3 to 6, 16. Previous records are Calgary, Pincher, Lethbridge and Medicine Hat.

Northwestern limits are Calgary and Halkirk.

This relatively scarce spring form is usually found in blow-out areas where there is considerable grama grass.

Cratypedes neglectus (Thos.)

1, 3, 4, 6, and 16. Previous records are Steveville, Fort Macleod, Macleod and Minda. Northern record is Hanna.

This is one of the rarer species in Alberta. It is found in much the same type of habitat as the previous species.

Dissosteira carolina (L.)

1, 3 to 6, 8, 15 and 16. Previous records are Lethbridge, Burdett, Medicine Hat, Walsh and Comrey.

This road-loving species is quite common in the southern part of the province. Its continuous distribution runs as far north as Rumsey and Youngstown. A single colony was found around a strip coal mine at Tofield in area 8. This record is 100 miles north of the previously known distribution.

Spharagemon equale (Say)

1, 3 to 7, 15. Previous records are Calgary, Brooks, Medicine Hat, Walsh, Minda, Manyberries, Orion, Bow Island, Whitla, Taber, Chin, Coaldale and Lethbridge.

The limits of northwestern distribution are Calgary and Wainwright.

Spharagemon collare (Scud.)

1, 3 to 8, 10, 15, 16. Previous records are Morrin, Calgary, Lethbridge, Bow Island, Medicine Hat, Walsh and Minda. Tinkham reports that he has collected it at Cold Lake.

The northwestern limits of distribution are Sundre, Ponoka, Bonnyville and Cold Lake.

Derotmema haydenii haydenii (Thos.)

1. First collected by Tinkham in 1938 at the Higdon Ranch, Comrey. It was taken from the same locality in 1939 (White and Neilson) and in 1940 (White and Rock).

Trachyrhachis kiowa kiowa (Thos.)

1 to 8. Previous records are Calgary, Lethbridge, Medicine Hat, Walsh, Minda and Comrey.

Camrose and McLaughlin are northern records.

This species is quite abundant in the plains section of the province.

Metator pardalinus (Sauss.)

1 to 8, 15 and 16. Previous records are Lethbridge, Macleod, Chin, Bow Island, Medicine Hat, Walsh, Cypress, Minda and Comrey.

Northern records of this species, common to grasslands, are Ponoka and Mannville.

Trimerotropis sparsa (Thos.)

1, 3 to 6. This variable species was first reported from Lethbridge in 1924 as *T. azurescens*. Since then it has been reported from Morrin, Drumheller, Lethbridge and Comrey.

The species is confined to eroded areas along cut banks in river valleys.

Trimerotropis gracilis sordida E. M. Walker

1, 3, 4 and 6. Previously reported from Brooks, Purple Springs, Bow Island, Whitla, Medicine Hat, Walsh and Minda.

Northwestern records are Lethbridge and Scapa.

The adults of this species are usually found in thin stands of dry short grass, along the edges of grain fields and in blow-out areas.

Trimerotropis pallidipennis salina McNeill

1, 3 to 7, and 9. Previous records are Edmonton, Steveville, Orion, Comrey, Bow Island, Lethbridge, Macleod and Waterton Lakes.

Edmonton is the northernmost record of occurrence.

This species has a somewhat discontinuous distribution due to the fact that it is largely confined to saline areas.

Trimerotropis campestris McNeill

1 to 7, and 16. Previous records are Gull Lake, Calgary, Morrin, Pincher, Macleod, Lethbridge, Chin, Medicine Hat, Cypress, Minda and Comrey.

Gull Lake and McLaughlin are northern records for this, the most common member of the genus, in Alberta.

Trimerotropis pistrinaria Sauss.

1, 3, 4, 5 and 6. Previously recorded from Lethbridge, Bow Island, Medicine Hat and Comrey.

Northwestern records are Gleichen and Scapa.

This handsome species is usually found along bare river banks and eroded and gravelly areas in bad lands.

Trimerotropis agrestis McNeill

3. Previous records are Orion, Minda and Calgary (Caudell).

This sand-loving species has only been taken by the authors at Orion. It is possible that the record of Caudell, from Calgary in 1908, of *citrina*, which has since been determined as *agrestis*, is due to mislabelling and that the specimen was caught at Medicine Hat.

Trimerotropis laticincta Sauss.

1 and 3. This species was first collected by Tinkham at the Higdon Ranch, Comrey, in 1938. Since then it has been collected from a number of locations in Area No. 1 and at Seven Persons in Area No. 3.

Trimerotropis suffusus Scud.

16. Previously recorded from Blairmore, Coleman, Frank and Waterton Lakes. It has not been collected by the authors from localities other than these.

Circotettix verruculatus Kirby

8, 9, 10, 12, 13, 14, 17, 18 and 19. Previous records are Cold Lake, Athabasca, Edmonton, Primrose Lake, Lacombe, Nordegg and Banff.

Banff, Lacombe, Edmonton and Cold Lake are southeastern records.

Circotettix rabula rabula R. and H.

1, 3 to 8, 15 and 16. Previous records are Morrin, Steveville, Coleman, Frank, Cowley, Fort Macleod, Macleod, Lethbridge, Medicine Hat and Comrey.

Cochrane, Delbourne and Meeting Creek are northwestern records. This species, which is largely confined to steep bare slopes, has a rather discontinuous distribution.

Aerochoreutes carlinianus carlinianus (Thos.)

1 to 8, 15 and 16. Previous records are Steveville, Macleod, Lethbridge, Welling, Bow Island and Comrey.

Cochrane and Meeting Creek are northwestern records in Alberta. It has, however, been reported by Buckell and collected by the authors in bare slopes of the Peace River at Rolla and Fort St. John, in the Peace River Block.

Hadrotettix trifasciatus (Say)

1 and 3. Previous records are Medicine Hat, Comrey and Calgary (Caudell).

This species has been collected by the authors only from the vicinity of Medicine Hat, Manyberries and Comrey. Caudell's record, from Calgary, is possibly due to the interchanging Calgary and Medicine Hat labels as probably occurred with his record of *T. vinculata similis* Scud.

(*T. agrestis.*) *Schistocerca lineata* Scud.

1 and 3. Previously recorded from Medicine Hat and Comrey. This species has been collected by the authors only from the vicinity of Medicine Hat, Manyberries and Comrey.

Hypochlora alba (Dodge)

1. New record for the province.

Reared from nymphs collected seven miles S.E. of Comrey, July 13, 1939 (White). Hebard (4) gave the northern limits of this species as Brockton, Nashua, Glasgow and Havre, Montana.

The food plant of this species, *Artemesia ludoviciana* Nutt., is fairly local in distribution over southeastern Alberta. *H. alba* appears to be even more localized and is confined largely to gullies in the area from which it was collected.

Aeoloplus turnbulli turnbulli (Thos.)

1 to 6. Previously recorded from Drumheller, Minda, Cypress and Comrey.

Morrin and Hanna are northern records of distribution.

This handsome little grasshopper, which feeds largely in *Atroplex* and its allies, has rather a discontinuous distribution.

Hesperotettix viridis pratensis Scud.

1, 3, 4, 5. Previously recorded from Lethbridge, Fort Macleod and Comrey.

The northwestern records of this handsome species are Brocket, Dorothy and Buffalo.

In Alberta this insect is usually found on or near, *Gutierrezia sarothrae* (Pursh.) which is one of its host plants.

Melanoplus oregonensis oregonensis (Thos.)

16. New record for the province.

Carway 8♂♂, 6♀♀, June 30, 1939 (R. M. White). Collected on the north slope of the Milk River ridge in *Symphoricarpos* and tall grass, at 4500 ft. elevation.

Three males have the supra-anal plate slightly shorter than material of *M. oregonensis oregonensis* from Wyoming although, in other respects, it is quite typical of this material. The other five males have the supra-anal plate slightly wider and slightly shorter than is usual in this species. The furculae are also slightly divergent but longer than is typical in *M. oregonensis triangularis* from Waterton. These five specimens are best described

as atypical *M. oregonensis oregonensis* as they are closer to that sub-species than to *M. oregonensis triangularis*. This location is apparently an area of intergradation between the two races.

M. oregonensis oregonensis had previously been recorded from Logan Pass, Glacier Park, Montana, by Hebard in 1932. This location is at an elevation of 6650 ft. and is 20 miles S.W. of Carway.

Melanoplus oregonensis triangularis Hebard

16 and 17. Previous records are Middle Fork of Old Man River, Coleman, Blairmore, Waterton and Lake Bertha in Waterton Lakes Park.

Of 58 ♂ ♂ and 16 ♀ ♀ none show any tendency toward *M. oregonensis oregonensis*. Three males of the series have the lateral margins of the supra-anal plate much raised and thickened in the proximal half.

Melanoplus montanus (Thos.)

10, 13, 16, 17, and 18. Previously recorded from Moraine Lake, Lake Agnes, Mount Fairview, Laggan, Banff, Crow's Nest Pass, Blairmore, Lake Bertha, Waterton Lakes Park, Cold Lake, Shaftesbury and Fairview.

The species has been collected by the authors only from Waterton, Bellevue, Coleman and Exshaw.

Melanoplus huroni Blatch.

10, 13, 19. Previously recorded from Shaftsbury.

This species, which is one of the rarer Melanopli of Alberta, has been collected by the authors from Cold Lake, and Bonnyville in Area 10, Jasper in Area 19 and in a number of localities in the Peace River district.

Melanoplus bivittatus (Say)

1 to 17 and 19.

This species, which had previously been reported from a number of localities in the province, has been the third most injurious of the economic species. Only individuals with bluish-yellow, greenish-yellow or straw-coloured tibiae have been taken.

Melanoplus dawsoni (Scud.)

2 to 10, 13, 15, 16, 17. This widely distributed species has been recorded from a number of localities in the province.

It is quite abundant in the more humid plains section and in the black soil of the park belt adjoining those areas. In the Peace River district, Area 13, the species is largely confined to the more open places along the river valleys.

A macropterous specimen was taken at Onefour in 1940 (Rock).

Melanoplus gladstoni (Scud.)

1 to 7 and 17. Previous records are Banff, Calgary, Fort Macleod, Macleod, Granum, Lethbridge, Bow Island, Cypress and Comrey.

Northwestern records of this insect, which is usually found in dry uplands, are Banff, Wimbourne and Wainwright.

Melanoplus confusus Scud.

1, 3, 5, 7 and 8. The first published record was of a single female from the Higdon Ranch, Comrey, taken by Tinkham on July 17, 1938 and reported in 1939.

The following additional records are available:

Ribstone, Aug. 12, 1937; Heath, July 7, 1938; Morningside, July 11, 1938; Edgerton, Dunn, Aug. 23, 1938; Elnora, Lousana, July 23, 1939 Rock).

Delbourne, July 10, 1938 (White and Rock).

Redcliff, June 7, 1938; Burdett, June 10, 1939 (White).

A single male is present from Estevan, Sask. collected, June 19, 1915 (N. Criddle).

These 27 ♂♂ and 15 ♀♀ all have glaucous tibiae ranging from quite deep to fairly weak. This is the earliest maturing species of the Melanopli, adults generally appearing about June 1. It is usually found in semi-upland locations or sand areas in close proximity to clumps of aspen poplars in Areas 5, 7 and 8. In the southern portion of the short grass prairies it is usually found close to trees along the river bottoms.

Melanoplus femur-rubrum femur-rubrum DeGeer

1 to 10 and 16. Previous records are Ponoka, Lethbridge, Medicine Hat and Walsh.

Northwestern records are Cowley, Calgary, Ponoka, Tofield and Myrnam.

This insect rarely reaches outbreak proportion in Alberta and then only in isolated, moist areas, particularly irrigated districts.

Melanoplus borealis borealis (Fieber)

18 and 19. New record.

This species was previously recorded from Banff and Beaverhill Lake as *extremus*, a synonym of *borealis borealis*, but this material was referred to *borealis monticola* by Hebard in 1930.

6 ♂♂ and 5 ♀♀ Athabasca Glacier, 6800 ft.: 4 ♂♂ and 4 ♀♀ Junction Athabasca and Whirlpool rivers, 5000 ft.: 1 ♀ Sunwapta Falls, 5000 ft.: 2 ♂♂ and 2 ♀♀ Mount Coleman, 6100 ft.: 8 ♂♂ and 9 ♀♀ Bow Summit, 6800 ft., July, 1939 and August, 1940 (Rock).

The material from Athabasca Glacier was collected within 50 to 200 yards of the glacier on springy soil covered by short, woolly grass, a species of low-growing birch and some mossy vegetation. There were numerous bare places with cherty exposures.

The specimens from Sunwapta Falls and the junction of the Athabasca and Whirlpool rivers and from Mount Coleman were collected in muskeg with a few dwarf birches and some short woolly grass. The specimens from Bow Summit were taken in a wide valley with a similar habitat to those from Athabasca Glacier.

These specimens were compared with, and found to be quite similar to, 2 ♂♂ of *borealis borealis* collected at Churchill, Manitoba, by D. C. Dunning, Aug. 9, 1937, and determined by A. B. Gurney. (Courtesy R. D. Bird). The specimens from the junction of the Athabasca and

Whirlpool rivers and from Sunwapta Falls are slightly larger than the Athabasca Glacier and Churchill material but still referrable to *borealis borealis*.

Specimens, determined by Hebard, have been collected at Cold Lake, Aug. 1937 (White and Rock) and at Cypress Hills (White).

Melanoplus borealis monticola Scud.

2, 4, 13, 14, 15, 17 and 19. Previous records are Cold Lake, Beaverhill Lake, Jasper, Mount Fairview, Lake Agnes, Laggan, Banff, Macleod and Cypress.

The authors are separating the *monticola* material into three groups based on wing lengths as this race is supposed to be separated from *borealis* largely on "the reduction in the organs of flight" (Hebard (3) P. 397).

(a) Tegmina not extending beyond the basis of the genicular lobes of the caudal femora, 3♂♂ and 23♀♀. Henry House, Leech Lake Jasper National Park, Marlboro, Goodwin, Valleyview, Debolt, Hines Creek, Dixonville, Deadwood, Nesta and Ryley.

(b) Tegmina extending to a point between the basis of the genicular lobes and just beyond the apices of the caudal femora, 36♂♂ and 11♀♀. Henry House, Obed, Marlboro, Goodwin, Beaverlodge, Hines Creek, Grimshaw, North Star, Nesta, Donnelly, McLennan, Joussard, Wagner, and Nestow in Alberta: Pouce Coupe and Baldonnell, B.C. in the Peace River Block.

(c) Tegmina extending well beyond the apices of the femora, 12♂♂ and 8♀♀. Valleyview, Goodwin, Grosmont, Beaverlodge, Hines Creek, Bluesky, Whitelaw, Grimshaw, Notikewin, Joussard, Smith, Athabasca, Nestow, Duffield and Seba Beach. Some of the specimens of this group, both males and females, have the tegmina extending as much as 7 mm. beyond the apices of the caudal femora.

Some *monticola* individuals, taken at altitudes of 1900 to 3800 feet, from various locations in Alberta, are larger and lighter in colour than *borealis*.

The penes were exposed in a number of specimens of different wing-length. Some variation in the penes was observed but this variation did not appear to be correlated with length of the tegmina.

In a number of publications Hebard has stated that "*monticola* is the least well defined of the races of *borealis*." With this the authors heartily agree. They are strongly of the opinion that *monticola* should be synonymized but hesitate to suggest it as they have only seen material of this race from Alberta, Wyoming, southern Utah and Manitoba.

They also wish to thank E. H. Strickland for the loan of his material of this race, determined by Hebard.

Melanoplus borealis junius Dodge.

13. New record.

One male, collected July 15, 1938, Valleyview, Peace River district (Rock). This male is, to all appearances, identical to two males from Senkiw and Aweme, Manitoba (R. D. Bird) which were determined by Hebard.

The authors are doubtful of the validity of this weakly defined race, although the only material of *junius* that they have seen is from Manitoba.

Melanoplus infantilis Scud.

1 to 11, 13, 16 and 17. This insect has been recorded from a number of localities, the northernmost being Leduc.

North of Edmonton it is confined largely to the dry hillsides along river valleys. It has been taken in such habitats as Beaverdam, Cold Lake, Peace River and Dunvegan. South of Edmonton it is found in large numbers in grasslands.

Melanoplus alpinus Scudder

2, 16, 17. Previous records are Crow's Nest Pass, Blairmore, Fort Macleod and Cypress.

The species has been collected from a number of locations in the Cypress Hills and in the foothills, the most northerly record being Canmore. Bruner's specimens from Fort Macleod were evidently taken in the foothills west of Macleod.

Melanoplus kennicotti kennicotti Scudder

4, 15, 16, 13, 16, 17. Previously recorded from Banff and the South Fork of the Old Man River near Fort Macleod.

The most northerly records are from Brownvale and Fairview, in the Peace River district. It is the most abundant grasshopper in Jasper Park. In the plains section of the province it is not common and adults are usually found in short dry grass. In the more moist areas it is found in dry grass along river banks.

Three males, which constituted the first record for British Columbia, were taken July 16, 1938 (White and Rock) on the north bank of the Peace River at Taylor.

Melanoplus occidentalis occidentalis (Thos.)

1, 3, 4, 5, 16. Previously recorded from Comrey and Lethbridge.

Northwestern limits of this uncommon grass species are Cowley and Drumheller.

Melanoplus fasciatus (F. Walker)

2, 8 to 17, 19. Previous records are Cold Lake, Athabasca, Edmonton, Laggan, several locations near Banff, Crow's Nest Pass, Blairmore and Cypress.

Apart from the Cypress Hills, southeastern records are Waterton Cowley, Exshaw, Alix and McLoughlin. This is a common species in mountainous and wooded areas. Macropterous specimens have been taken at Perryvale, Athabasca, Lesser Slave Lake, McLennan, Hines Creek and Valleyview. A previous Edmonton record is based on the macropterous form.

A gynandromorphic specimen is in the collection from Sturgeon Heights, Peace River district, July 17, 1938 (Rock.) Male characteristics are visible in the insect only in the genitalia, of which the right half is male and the left half female. In detail, the cerci are complete and normal on

each side—a male cercus on the right and a female cercus on the left. The supra-anal plate is a combination of male and female characters; the right half has male characters, including the ridge adjacent to the median sulcus, and a fercula but the left half is almost typically feminine, lacking ridge and fercula. The male sub-genital plate is almost complete on the right side of the median line but the left half has the appearance of having had the apical half cut out. One dorsal and one ventral ovipositor valve is present in the left side but both valves are displaced distad-laterad. Except for their displacement they appear to be quite normal.

Melanoplus mexicanus mexicanus (Sauss.)

This, the most destructive species of the orthoptera in Alberta, has been recorded in the literature from a number of localities southeast of Lake Louise and Wetaskiwin.

Typical material was collected in a large number of localities in Areas 1 to 8, 16, 17 and from Perryvale and Athabasca in Area 12, Beaverlodge and Debolt, Area 13, and Taylor in the Peace River Block.

There is a typical material, in which the subgenital plate is more produced and not conspicuously notched and the furculae are much longer and heavier than in typical *mexicanus*, from the following points: Waterton, Banff, Castor, Hughendon, Edson, Obed, Beaverlodge, Grimshaw and from Taylor, B.C.

Melanoplus bruneri Scudder

2, 7 to 19. Area 19 is the only new record of distribution.

A typical material, in which the ferculae are shortened and the subgenital plate less produced than in typical *bruneri*, was collected from Mountain View, Banff, Morley, Jasper, Wabamun, Edmonton, Myrnam, Bonnyville, Nestow, Peace River, Debolt, Fairview and Taylor, B.C.

In the transitional area of this province, where the park belt approaches prairie conditions, specimens which apparently intergrade between *bruneri* and *mexicanus* can be found. It would appear to the authors that *M. bruneri* might well be relegated to racial status, under *M. mexicanus*, as it appears to be merely a boreal form of that species.

Melanoplus keeleri luridus (Dodge)

3. Previously recorded from Minda, in Area 3.

This species has not been collected by the authors.

Melanoplus packardi packardi Scudder

1 to 16, 19. Previously recorded from Calgary, Fort Macleod, Lethbridge, Chin, Whitla, Medicine Hat, Minda and Comrey.

Jasper, Peace River, Perryvale and Cold Lake are northern records. A number of specimens were taken in the Jasper district, near Peace River and at Perryvale in which the rear tibiae were lilac-coloured when collected but which turned deep red when dry. These were determined by Mr. A. B. Gurney.

This, the fourth most injurious grasshopper to crops in Alberta, is quite plentiful over a wide range of habitats in Areas 1 to 11. All of the specimens taken in these areas have glaucous tibiae.

Melanoplus foedus foedus Scudder

Orion, in Area 3. New record for the province. A single male was collected among sand dunes at Orion, July 14, 1939 (White). Without examination of the internal genitalia the specimen would have been identified as *packardi*. Caudal tibiae are glaucous.

The previous northwestern records for the species as given by Hebard in 1932 were Missoula, Cascade and Forsyth, Montana.

Melanoplus foedus fluviatilis Bruner

4. New record.

A single teneral male was collected at Lethbridge, Aug. 10, 1933 (White) and determined by A. B. Gurney.

Columbus, Pompey's Pillar and Terry, Montana, are previous northwestern records.

This record is approximately 325 miles northwest of any previous record of distribution.

Melanoplus angustipennis (Dodge)

3 and 7. New to the province.

Previous northwestern limits for this inhabitant of sandy areas were Tortman, Glasgow and Poplar, Montana and Aweme, Manitoba.

5♂♂, 6♀♀, July 13, 1933, July 14, 1939 (White); 1♂ Orion, July 14, 1939 (C. L. Neilson); 1♂, 1♀, Czar, Aug. 18, 1938, 2♂♂,2♀♀, Hughendon, Aug. 23, 1939, 7♂♂, 6♀♀, Orion, July 16, 1940, 1♂, Comrey, July 14, 1940 (Rock).

Melanoplus flavidus flavidus Scudder

3, 4, 5 and 7. Previous records are Drumheller, Lethbridge and Medicine Hat.

The northern record of this grass-feeding inhabitant of sand areas is Heath.

There is a possibility that the previous records from Lethbridge, Medicine Hat and Drumheller refer to *M. bowditchi canus*. Although *flavidus* and *bowditchi canus* are easily distinguishable in the field, difficulty was experienced in separating dried material until the penes were compared.

The writers have taken authentic specimens of *flavidus* only from Metiskow, Hughendon, Amisk, Heath, Ribstone and Orion.

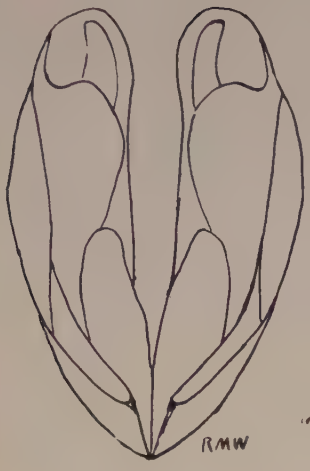
Melanoplus bowditchi canus Hebard.

1, 3, 4 and 5. Previous records are Morrin, Lethbridge, Medicine Hat and Comrey.

Morrin and Empress are northern records.

This inhabitant of sage brush areas has been taken only from around, or on, *Artemesia cana* Pursh. and is usually confined to eroded areas and river valleys. Dried specimens may easily be confused with *M. flavidus* but are readily distinguished by comparing the penes.

Drawings of this organ of *M. flavidus* and of *M. bowditchi canus* are shown in Figures 2 and 3, respectively.



a. Caudal View

Fig. No. 2
Penis
M. flavidus

b Lateral View

a. Caudal View

Fig. No. 3.
Penis
M. bowditchi canus

b. Lateral View

FIGURES 2 AND 3

Asemoplus montanus (Bruner)

16. This previously incorrectly recorded species was first collected by E. R. Buckell at Bellevue. Material was collected at Waterton and Bellevue, Sept. 19 and 20, 1939 (White).

The species had been reported in error from Waterton by Hebard in 1928, but this was corrected by him in 1930, the material actually representing *A. somesi* Hebard.

Asemoplus somesi Hebard

16 and 17. Previous records are Banff, Lake Louise, Blairmore, Waterton and Lake Bertha, Waterton Lakes Park. This species has been collected by the authors only from the above localities.

Asemoplus hispidus (Bruner)

Hebard, in 1930, writes of this species, "The only record of this species, to which *somesi* is closely related, is that part of the original series of the synonym *Podisma nuda* Walker from Mount Piron near Laggan (Lake Louise)."

The authors have not collected it.

Phoetaliotes nebrascensis (Thos.)

1, 3, 4 and 5. Previous records are Fort Macleod, Macleod, Lethbridge, Medicine Hat. Walsh and Comrey.

Northern records of this rather uncommon species of the grasslands of southern Alberta are Gleichen and Hilda.

ACKNOWLEDGMENTS

The authors are greatly indebted to Prof. E. H. Strickland, University of Alberta, for permission to use his data in the Description of Ecological Areas. These descriptions were found to be remarkably complete, accurate and just the information required.

Gratitude is expressed also to Messrs. A. B. Gurney, M. Hebard, J. A. G. Rehn, H. C. Severin and E. R. Buckell for their determinations of material.

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PINK ROT DISEASE OF POTATOES IN BRITISH COLUMBIA[1]

WALTER JONES[2]

Dominion Laboratory of Plant Pathology, Saanichton, B.C.

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In the autumn of 1943 a few diseased potato tubers that exhibited symptoms not previously seen by the author were obtained from the Okanagan district of British Columbia. These symptoms were somewhat similar to those associated with blackleg and *Pythium* soft rot. On microscopic examination, coenocytic mycelium was found within the diseased tissue, and when the fungus was isolated and cultured it was identified as *Phytophthora erythroseptica* Pethy. This was first described by Pethybridge (1) as the cause of the pink rot disease of potatoes in Ireland. According to McLarty (2), the disease was found in localized areas of one Okanagan field, and caused a crop loss of approximately 30% owing to wilt, stem decay, and the rotting of the tubers.

EXPERIMENTAL METHODS AND RESULTS

Symptoms of Diseased Tubers

In artificially inoculated tubers of different varieties, the most characteristic external sympton was a dark discoloration of the lenticels. This was quite pronounced in the young tubers and in the tubers of white skinned varieties (Plate 1). Where it was possible to skin the affected parts, the tissue adjacent to the lenticels appeared as distinct black spots on the surface of the dull white flesh. Other external symptoms were a dullness of the skin and a purplish discoloration of the eyes. The surface discoloration varied with the varieties. Thus, in the Netted Gem and the Columbia Russett varieties, the diseased tubers appeared almost normal, while in the Burbank and the White Rose varieties, the diseased areas were much darker than the healthy areas (Plate 1). The affected tubers were fairly firm but somewhat resilient, and when pressed, a brownish watery liquid oozed through the broken skin. These latter symptoms are somewhat similar to those associated with the tuber soft rot caused by *Pythium ultimum* Trow., as reported by Jones (3).

Immediately after cutting, the flesh of the diseased tubers appeared dirty white and moist, but after a few minutes exposure to the air, a faint pink colour developed. Within a half-hour period, the whole of the cut surface assumed a deep salmon pink colour which after a long exposure, changed to a purplish black. When the affected tubers were kept relatively dry, the texture of the diseased tissues remained fairly firm and somewhat leathery, but when kept in a moist chamber or in the soil, they rotted, and whitish mycelial tufts of secondary organisms developed on the lenticels. In general, the above symptoms agree with those described by Pethybridge (1).

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[1] Contribution No. 814 from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Assistant Plant Pathologist.

The Pathogen

The fungus grew readily in culture, and on malt and potato dextrose agar media produced numerous oospores. When pieces of mycelium were transferred to a solution of M/100 potassium nitrate, a few sporangia developed. These were usually single and terminal but on rare occasions the conidiophores were sympodially branched (Plate 2). The morphological characteristics of the oogonia, the antheridia, the oospores, the sporangia, and the mycelium agree with those described by Pethybridge (1).

Pathogenicity of the Fungus to Tubers of Different Varieties

Five potato tubers each of the varieties Warba, Epicure, Irish Cobbler, White Rose, Netted Gem, Burbank, Green Mountain, Columbia Russett, and Sequoia were used for this experiment. By means of a cork borer, tissue was taken out from the stem end of each tuber to a depth of a quarter of an inch. After uniform discs of an actively growing culture were placed inside the cavities, the plugs of the tuber tissue were re-inserted and sealed with paraffin wax. The tubers were then incubated at 24° C.

All the tubers developed symptoms of the pink rot disease, and after 6 days, no significant difference in varietal susceptibility was found.

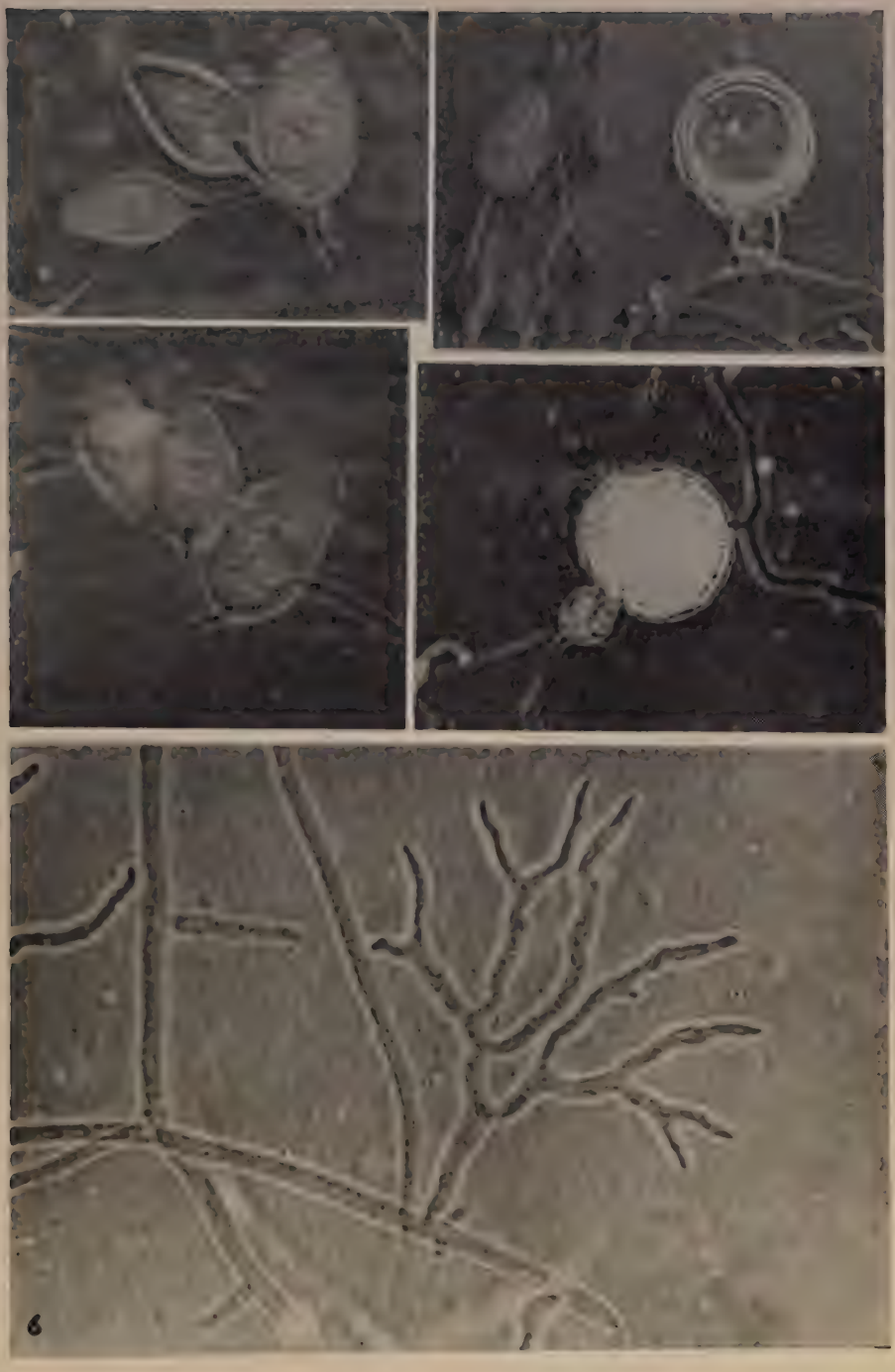
Pathogenicity of the Fungus to Growing Plants and Tubers

This was determined in the greenhouse by planting potato tubers of the Warba variety in steam sterilized soil, and in steam sterilized soil inoculated with diseased potato tissue obtained from artificially inoculated tubers. Two test series were run, with 10 inoculated and 5 check pots in each series.

Inoculation of the soil was done by cutting diseased tubers into quarters and placing 8 of these quarters a few inches below soil level in each pot. Small whole tubers of the Warba variety, previously dipped in an organic mercury solution were then planted. In the first series, the potatoes were planted in February, and the plants dug up and examined 20 days later before any tubers had developed. In the other series, the potatoes were planted in March, and the plants were allowed to grow until good sized tubers had developed.

In the first series, all the check plants grew normally. In the inoculated pots, 4 of the mother tubers had rotted, and 6 were normal. The sprouts that grew from 5 of the tubers showed brown, necrotic lesions rather similar to those associated with Rhizoctonia infection (Plate 1). Within this necrotic tissue, oospores of the fungus were present.

In the second series, all the plants and tubers in the check pots were healthy. In the inoculated pots, all the plants grew normally throughout the early growth period, but a few leaves of some of the plants wilted during the later stages of growth. The harvested tubers of 2 plants were all healthy, while the tubers of 1 plant were all affected with the pink rot disease. Each of the other 7 pots contained some healthy tubers and some tubers affected with pink rot. On a few stems, the tissues of the basal parts were shrunken and necrotic, and aerial tubers were produced on the stems of 2 plants (Plate 1).



Symptoms of the pink rot disease on potato tubers and plants.

1. Young tubers—Left, healthy; Right, diseased.
2. External symptoms on tubers of Netted Gem, Burbank, White Rose, Sequoia and Columbia varieties.
3. Left, check. Right, necrosis of base of stem and formation of aerial tubers caused by the fungus.
4. A and B. Showing necrosis of stems and decay of mother tubers. C. Check.

PLATE II

1 and 2. Sporangia showing sympodial branching. 3. A terminal sporangium. 4. Mature oospore. 5. Oogonium and antheridium. 6. Mycelim showing mode of branching.

× 400

Growth Temperature of the Fungus

Inoculum from an actively growing culture was transferred to plates containing malt agar and incubated at the following temperatures: 4° C., 8° C., 20° C., 24° C., 28° C., and 34° C. Five plates were used for each series. After 6 days, the average growth was respectively 0, 2, 6, 7.5, 3.5 and 0 centimetres in diameter. The results indicate that the optimum temperature for growth of the fungus is approximately 24° C., the minimum between 4° C. and 8° C., and the maximum below 34° C.

Pathogenicity of the Fungus to Potato Tubers at Different Temperatures

Potato tubers of the Burbank variety were used in this experiment because the external symptoms of the disease are well defined in this variety. Thirty tubers were inoculated with a pure culture of the fungus and incubated at 4° C., 8° C., 20° C., 25° C., and 28° C., with 6 tubers at each temperature.

The rate of infection was determined by measuring the extent of the decay from the stem to the apical ends, with index "one" representing the maximum decay. Slight symptoms of the disease were observed on the second day in the series incubated at 20° C., 25° C. and 28° C. On the fifth day, the average indices of infection at these temperatures were .5, .8 and .6, and on the sixth day, .7, 1.0, and .8, respectively. At the end of the sixth day there were no symptoms of decay in the tubers incubated at 4° C. and 8° C.

These results indicate that the optimum temperature for the development of the pink rot disease in potato tubers is approximately 25° C.

DISCUSSION

Pethybridge (4) claimed that the parasite was found in all the underground parts of the plant, and that oospores were present in the diseased tissue. He also stated that the parasite can cause a wilt disease which usually appears late in the season, and that frequently a crop of small aerial tubers may be produced. These observations agree with the results obtained in the above pathogenicity experiment with growing plants. It is interesting to note that cortical necrosis of the sprouts as well as the formation of aerial tubers are field symptoms usually attributed to Rhizoctonia infection. In this experiment, there was a slight wilting of some of the leaves of the plants which were grown in the inoculated pots, but otherwise there was no significant difference between them and those grown in the check pots. Numerous tubers, however, of the plants grown in the inoculated soil were affected with the pink rot disease. This indicates that the disease is essentially a tuber disease, and that infection of tubers may occur in the soil during growth where the pathogen is present.

Control Measures

To control the disease, Pethybridge (4) recommends growing potatoes only on land in proper rotation, and the removal and destruction of all affected parts, including the diseased tubers.

Since the optimum temperature for the growth of the fungus is approximately 24° C., and that for the development of the disease in tubers is

approximately 25° C., it is obvious that care should be taken to remove all diseased tubers at harvesting time. This is particularly important in the case of tubers harvested during warm weather, and in those stored or shipped at relatively high temperatures.

SUMMARY

1. The fungus *Phytophthora erythroseptica* Pethy., the causal organism of the pink rot disease, was isolated from diseased potato tubers obtained from the Okanagan district of British Columbia.

2. The symptoms of the disease in inoculated tubers are a dark discoloration of the lenticels, a dullness of the skin, and purplish discoloration of the eyes; the flesh on cutting is dirty white, turning to faint pink, then to deep salmon pink within one-half hour.

3. The fungus proved pathogenic to potato tubers of the varieties Warba, Epicure, Irish Cobbler, White Rose, Netted Gem, Burbank, Green Mountain, Columbia Russett and Sequoia. All appeared to be equally susceptible.

4. Plants grown in soil inoculated with the fungus developed symptoms of pink rot in the mother tubers and in young tubers, as well as necrosis of stolons, sprouts, and basal parts of the stems, and wilt of some of the leaves towards the end of the growing period.

5. The optimum temperature for the growth of the fungus is approximately 24° C., the minimum between 4° C. and 8° C., and the maximum below 34° C.

6. The optimum temperature for the development of the disease in potato tubers of the Burbank variety is approximately 25° C.

7. Control measures consist in crop rotation, destruction of diseased refuse, and careful grading of the crop before putting in storage or before marketing.

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THRESHING-INJURY TO FLAX SEED IN CANADA[1]

J. E. Machacek and A. M. Brown[2]

Dominion Laboratory of Plant Pathology, Winnipeg, Manitoba

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In 1940, when 62 different lots of No. 1 C.W. commercial flaxseed, treated and untreated, were sown in non-sterile soil in a greenhouse, it was found that in some lots the treated seed showed a marked improvement in germination, while in other lots the treated and the untreated seed germinated equally well. At first it appeared that this difference was due to some varietal influence, or to a variation from lot to lot in the percentage of seeds infected with pathogenic micro-organisms. Subsequent tests revealed that neither of these factors was apparently involved. There was frequently a greater difference, in their response to seed treatment, between two seed lots of any given variety than there was between two seed lots of different varieties. A plating-out test of non-sterilized seed showed that the seed responding most markedly to seed treatment was often relatively free from micro-organisms. Furthermore, when the 62 lots of commercial seed were planted in autoclaved soil, in almost every case the untreated seed germinated as well as did the treated seed. These findings indicated that soil-borne, instead of seed-borne, micro-organisms were responsible for the differences in seed germination observed when treated and untreated flax seed was planted in non-sterile soil.

It was not until seed from different lots of flax was scrutinized through a low-power binocular microscope that the cause of the differences in seed germination became apparent. The seed lots responding to seed treatment contained fractured kernels (Figure 1B) in percentages proportional to the degree of response to seed treatment. These fractures were usually minute and escaped observation by the unaided eye, but they were deep, and in most kernels extended into the cotyledons. It appeared, therefore, that, when fractured kernels were planted in non-sterile soil, soil-borne micro-organisms invaded the kernels through the fractures and prevented them from germinating. On the other hand, when the seed was treated, the kernels were protected from such invasion and, on germination, produced seedlings with cotyledonary leaves bearing scars where the fractures had occurred (Figure 1C).

An investigation showed that fracturing of flax kernels occurred when the seed was threshed by machines equipped with a steel threshing cylinder. There was no fracturing when flax was threshed by hand or when the plants were passed between two rubber rollers.

In view of the increased importance of the flax crop during the present wartime emergency, it was thought desirable to investigate the prevalence and the economic significance of threshing-injury to flax in Canada, and to study ways of preventing losses from this injury. A preliminary report regarding this investigation has already been published (3). The results of more detailed experiments, carried on from 1940 to 1943, inclusive, are summarized and discussed in this paper.

[1] Contribution No. 828 from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Assistant Plant Pathologists.

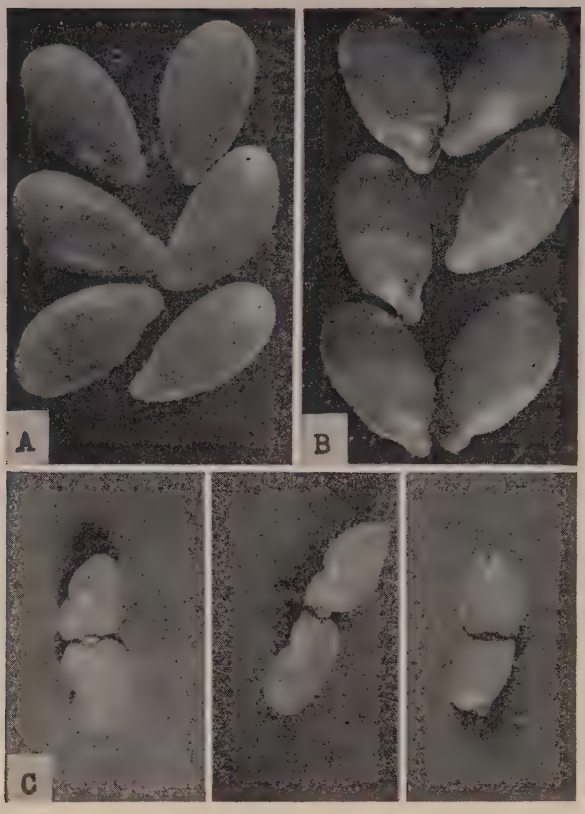


FIGURE 1. Threshing-injury to flax seed. A. Uninjured kernels. B. Fractured kernels. C. Seedlings from treated, fractured seed showing scars on cotyledonary leaves.

REVIEW OF LITERATURE

It appears that Stevens (7) was the first to draw attention to threshing-injury in flax. He reported that fractured kernels germinated poorly in the germination chamber and in the field. Härtel (2) also found that fractured flax kernels germinated poorly in the laboratory, and suggested that the seed became fractured when the crop was threshed during excessively dry weather. Schuster and his co-workers (6) reported that threshing-injury to flax occurred in the State of Washington. Their findings, in general, were similar to those obtained earlier (3) by the present writers. Moore and Christensen (5) found that mechanical fracturing of the seed coat was prevalent in flax seed from the United States and from Canada, and that injured seed, particularly that of golden-seed varieties, responded more to seed treatment than did uninjured seed.

MATERIALS AND METHODS

The flax seed used in the present investigation was obtained from a number of different sources. Thus, for a survey of the prevalence of threshing-injury in Canada, a large number of seed samples were obtained from farms, either directly or through the agency of various elevator com-

panies (North-west Line Elevators Association, Manitoba Pool Elevators Ltd., and United Grain Growers Ltd.) and the Manitoba Department of Agriculture. For a study of the relation of threshing-injury to market grade, samples from carload lots of flax seed were obtained through the courtesy of the Grain Inspection Division, Department of Trade and Commerce, Dominion of Canada. Additional seed lots, drawn from various experimental farms and stations across Canada, were used to determine the amount of threshing-injury in different varieties of flax. Finally, uninjured lots of seed were obtained by threshing flax plants by means of an ordinary clothes wringer.

The percentage of fractured kernels in a sample of flax seed was determined by one or more of the three following methods:

Method 1. A 100-kernel lot was spread in a one-layered narrow band on the adhesive side of a cellulose tape (Durex). The tape, with the attached seeds, was then drawn slowly across the field of a low-power binocular microscope and a count was made of the fractured kernels.

Method 2. A 100-kernel lot was taken from a seed sample, treated with diluted New Improved Ceresan, and then planted in non-sterile soil in the greenhouse. When the seedlings had emerged they were counted, and then a second count was made of the seedlings with scarred cotyledonary leaves (Figure 1C). The ratio of the second total to the first total was used to obtain the percentage of deeply-fractured kernels.

Method 3. Two 100-kernel lots were taken from each seed sample and, after one of these lots had been treated with diluted New

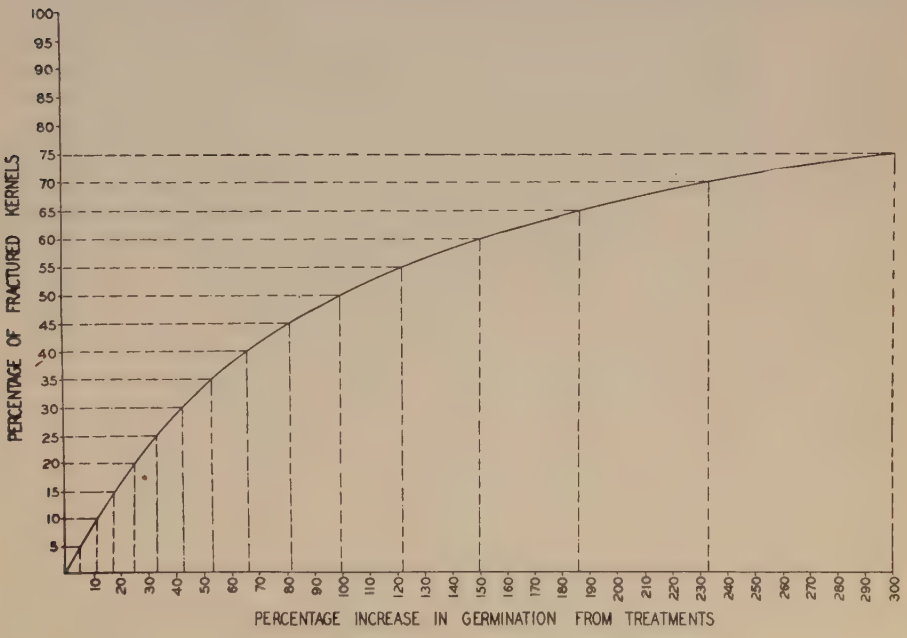


FIGURE 2. Relation of the percentage of fractured kernels in flax to the percentage increase in germination resulting from seed treatment.

Improved Ceresan, both lots were planted in adjacent rows in a bed of non-sterile soil. The percentage increase in germination resulting from seed treatment was determined and this value was interpolated on the graph shown in Figure 2. This interpolation showed, on the ordinate axis, the percentage of fractured kernels in the seed. The method was found to be inaccurate for seed containing many kernels infected by pathogenic micro-organisms, for the readings from the graphs were too high in comparison with the values obtained by Methods 1 and 2. As the majority of the flax seed samples tested were relatively free from infection and considerable information regarding the seed could be obtained through this method, it was the one generally followed.

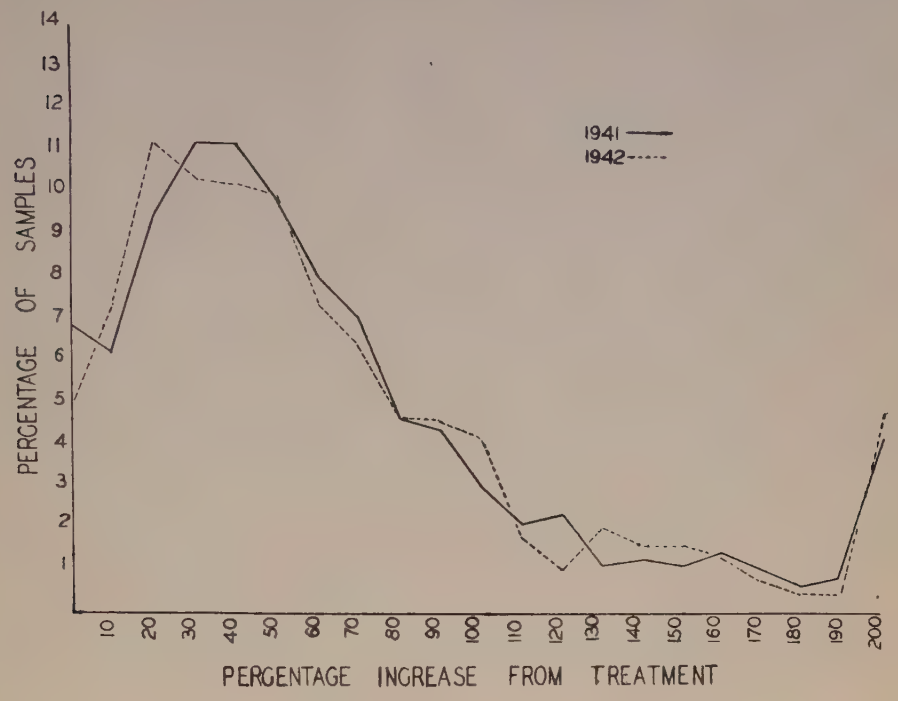
In experiments to compare the protective value of different seed disinfectants, the disinfectants were usually applied as prescribed by their manufacturers. In routine tests, however, diluted New Improved Ceresan was regularly used to treat the seed. This disinfectant was chosen primarily because it was the one most readily available during the period of this study. When it was used diluted, one volume of it was mixed with two volumes of talc. In treating seed, a small quantity of the dilute disinfectant was poured into a glass beaker, the seed was then added, and, after thorough mixing, the excess dust was screened off into a second beaker. By a series of determinations with mixed lots of flax seed, it was found that the maximum amount of dust retained on the seed was 13.79 ounces to the bushel. This quantity of dust did not seem to harm the seed at all and its use prevented the loss of time required for the weighing out of minute quantities of undiluted dust. The protection afforded by this load of dilute dust was found to be about equal to that given by 1.5 ounces of undiluted New Improved Ceresan added to a bushel of seed.

The soil used for the tests was previously adjusted to a suitable degree of friability by a method described elsewhere (4). In all experiments, except those in which soil temperatures were involved, the soil was placed in frames on greenhouse benches. In experiments involving soil temperatures, the soil was put in 1-gallon earthenware jars held in Wisconsin-type temperature tanks. When sterile soil was required, the adjusted soil was put in 1-gallon containers and steamed for 3 hours at 15 pounds pressure.

The majority of the field experiments discussed in this paper consisted of 3-row plots (rows 10 feet long and 1 foot apart) arranged in randomized blocks, with at least 6 replicates of each treatment, and sown by hand. The middle row in each plot was used to obtain information regarding seed germination and yield, while the 2 lateral rows were used as buffers. In other field experiments, the plots were 1/100 acre in size and were arranged either in randomized blocks or in Latin squares. These larger plots were sown with a horse-drawn drill which spaced the rows 6 inches apart.

In the greenhouse, where the temperature was held at approximately 70° F., counts of plants were made 10 days after the seed was sown. In the field, however, the plants were not counted until they were mature.

When the plants in the field were ripe, those in the 10-foot row experiments were pulled, and then threshed by passing them between the rollers



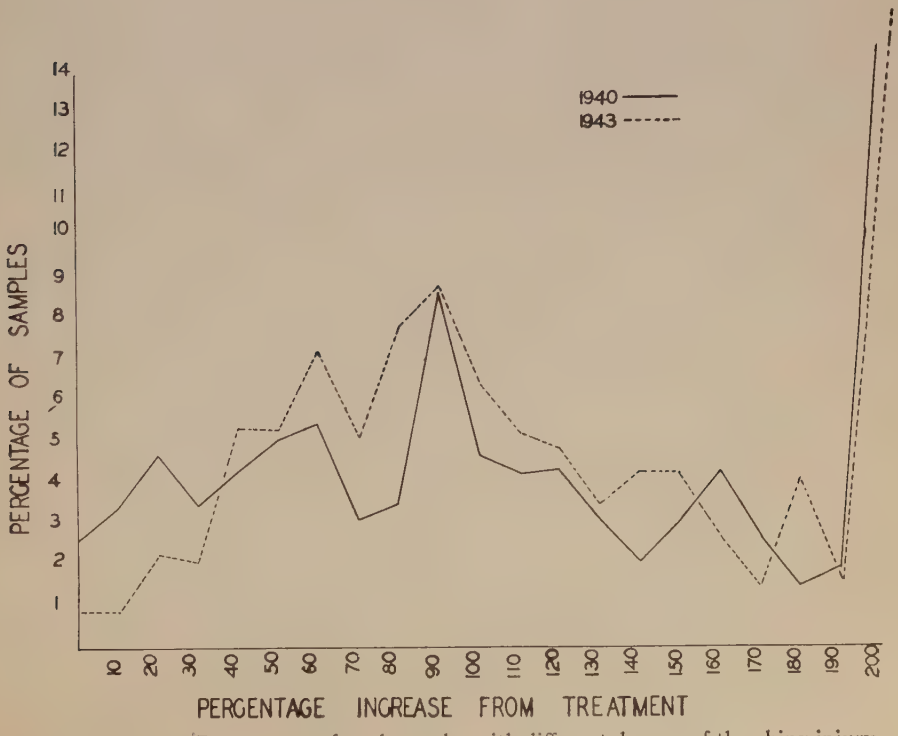


FIGURE 3. Percentages of seed samples with different degrees of threshing-injury. Aobve: crops of 1941 and 1942. Below: crops of 1940 and 1943.

of an ordinary hand-operated clothes wringer. The plants in the 1/100 acre plots were usually cut, after the border rows had been discarded, with a binder, and then threshed with a power-driven, stationary thresher.

Germination and yield data of most of the greenhouse and field experiments reported in this paper were analyzed statistically by the analysis of variance method.

PREVALENCE OF THRESHING-INJURY IN CANADA

General Distribution

In all, 2,630 samples of flax seed from different parts of Canada, and produced during the years 1940 to 1943, inclusive, were tested for threshing-injury. These tests showed that, in the 253 samples of the 1940 crop that were tested, on the average 52% of the kernels were fractured, while in 1,161 samples from the 1941 crop, in 608 samples from the 1942 crop, and in 608 samples from the 1943 crop, the average percentage of fractured kernels was 35%, 35%, and 52%, respectively.

The striking similarity in the percentage of fractured kernels between the crops of 1940 and 1943, and between those of 1941 and 1942, was emphasized by a further comparison of seed samples. When these samples were grouped in classes according to the percentage increase in seed germination resulting from seed treatment, it was found (Table 1) that the percentage of samples falling into corresponding classes was similar for the years 1940 and 1943, and also for the years 1941 and 1942. These similarities are shown graphically in Figure 3.

TABLE 1.—EXTENT OF THRESHING-INJURY IN THE FLAX CROPS OF 1940, 1941, 1942, AND 1943. THE PERCENTAGE OF SEED SAMPLES AT DIFFERENT LEVELS OF SEED INJURY

Level of threshing-injury (Increase in seed germination from treatment	Percentage of seed samples							
	Actual percentage at level of injury indicated				Total percentage with injury at level indicated or higher injury			
	1940	1941	1942	1943	1940	1941	1942	1943
0 – 10	2.7	6.9	5.0	0.9	100.0	100.0	100.0	100.0
11 – 20	3.5	6.2	7.4	0.9	97.1	92.9	93.5	98.9
21 – 30	4.7	9.5	11.3	2.3	93.5	86.6	86.1	97.9
31 – 40	3.5	11.3	10.5	2.1	88.8	77.0	74.8	95.6
41 – 50	4.3	11.3	10.3	5.2	85.2	65.7	64.2	93.4
51 – 60	5.1	9.9	10.0	5.2	80.9	54.3	53.9	88.1
61 – 70	5.5	8.0	7.5	7.2	75.8	44.4	43.8	82.8
71 – 80	3.1	7.0	6.4	5.0	70.2	36.4	36.3	75.6
81 – 90	3.5	4.6	4.7	7.8	67.1	29.3	29.9	70.5
91 – 100	8.6	4.4	4.6	8.8	63.5	24.7	25.1	62.7
101 – 110	4.7	3.1	4.2	6.4	58.8	20.2	20.5	53.9
111 – 120	4.7	2.2	1.9	5.2	50.1	17.0	16.2	47.5
121 – 130	4.3	2.4	1.1	4.8	45.4	14.8	14.2	42.2
131 – 140	3.1	1.2	2.1	3.5	41.0	12.4	13.1	37.3
141 – 150	2.7	1.3	1.6	4.3	37.9	11.1	11.0	33.8
151 – 160	3.1	1.2	1.6	4.3	35.1	9.7	9.3	29.5
161 – 170	4.3	1.4	1.4	2.7	31.9	8.5	7.7	25.2
171 – 180	2.7	1.1	0.8	1.5	27.6	7.0	6.2	22.4
181 – 190	1.5	0.6	0.4	4.1	24.8	5.9	5.4	20.9
191 – 200	1.9	0.8	0.4	1.7	23.3	5.2	4.9	16.8
201 +	21.3	4.3	4.4	15.0	21.3	4.3	4.4	15.0

It was most difficult to account for the similarities within the pairs of years and for the differences between the pairs. After an examination of several possibilities, it was concluded that coincidental similarities in weather conditions prevailing during threshing were responsible. The weather was relatively dry at threshing time in 1940 and 1943 (threshing-injury severe), while, in 1941 and 1942 (threshing-injury moderate), it was moist. This conclusion was supported by the observations of Härtel (2), and also by the results obtained from a study of the market grades of flax seed from the crops of these four years. The flax from the crops of 1940 and 1943 graded well, most of it falling into grade No. 1 C.W. or No. 2 C.W. Some of the seed of the 1941 and 1942 crops fell into these high grades, but the bulk of it, chiefly on account of weathering and moulding resulting from prolonged moist weather, fell into lower grades. It appeared, therefore, that dry flax seed was very brittle and easily fractured during threshing, while flax seed of relatively high water content, being less brittle and also buffered to some extent by the spongy material from moist bolls, was not so subject to injury. A few seed lots from the 1941 and 1942 crops were weathered as well as fractured, and many of the kernels were actually fragmented. This condition of the seed indicated that an attempt had been made to thresh the flax when it was damp; and, to overcome the difficulty involved, the teeth of the concaves and cylinder of the thresher had been set too close, with the result that the seed received considerable injury even though it was damp.

Occurrence of Threshing-Injury in Different Areas

Most of the samples of flax seed studied originated in Western Canada (Manitoba, Saskatchewan, and Alberta), and only relatively few in Eastern Canada. This unequal distribution in respect to the source of seed did not permit a fair comparison of the two areas in respect to the prevalence of threshing-injury in them; but the results of the tests suggested that the seed from Eastern Canada, probably on account of moister weather at threshing time, was much less injured than that from Western Canada.

The distribution of threshing-injury in Western Canada is shown in Table 2. In each year of the four years during which seed samples were tested, flax seed originating in Manitoba was slightly less injured than that from Saskatchewan and Alberta. This difference, again, could be attributed only to a difference in weather conditions during threshing.

Occurrence of Threshing-Injury in Different Commercial Grades of Flax

Tests with 565 officially-graded samples of flax seed showed (Table 3) that there was apparently no relation between the commercial grade of flax seed and the percentage of fractured kernels in it. This result might be expected, because flax seed is graded largely on the basis of its appearance; that is, high grades are given to seed that is bright and glossy, while low grades are given to seed that is dull and off-colour. The appearance of the seed depends, however, on the kind of weather *before* it is threshed, while the percentage of fractured kernels in the seed seems to depend on the kind of weather *during* which it is threshed. Thus, bright seed, as well as weathered seed, will contain many fractured kernels when threshed during dry weather and relatively few when threshed during moist weather. On

this account, lightly-fractured and severely-fractured lots of seed may fall into the same grade, and, as the present observations indicate, the average injury to seed may be no greater in one grade than in another.

TABLE 2.—AVERAGE PERCENTAGE OF FRACTURED KERNELS IN FLAX SEED PRODUCED IN MANITOBA, SASKATCHEWAN, AND ALBERTA DURING 1940, 1941, 1942, AND 1943

Crop year	Province			Mean
	Manitoba	Saskatchewan	Alberta	
1940	49	63	51	51.0
1941	33	37	36	35.3
1942	32	35	34	33.6
1943	47	51	54	50.6
Mean	40.2	46.5	43.7	

TABLE 3.—AVERAGE PERCENTAGE OF FRACTURED KERNELS IN DIFFERENT COMMERCIAL GRADES OF FLAX IN 1940, 1941, 1942, AND 1943

Grade	Crop year			
	1940	1941	1942	1943
No. 1 C.W.	52	36	27	52
No. 2 C.W.	—*	33	30	47
No. 3 C.W.	—	35	27	43
No. 4 C.W.	—	34	—	—

* No samples available.

Occurrence of Threshing-Injury in Different Varieties of Flax

It was suggested earlier (3), and this view received support by Schuster *et al.* (6), that threshing-injury was more severe in large-seeded varieties of flax than in small-seeded ones. A recent study of 15 varieties of flax grown at each of nine experimental stations in different parts of Canada, and in two different years, indicated that there was a relatively close relation between the size of flax kernels and the percentage of them that were fractured. Data relating to 4 of these varieties are given in Table 4. Two of these varieties (Royal and Bison) are large-seeded and were, for the 15 varieties studied, on one end of the kernel-size scale, while the other 2 varieties (Redwing and Gossamer) are small-seeded and were at the other end of the kernel-size scale. The weights, per 1000 kernels obtained from composites made up of 16 samples of each variety, were as follows: Royal, 5.90 gm., Bison, 5.60 gm., Redwing, 4.77 gm., and Gossamer, 4.35 gm.

TABLE 4.—RELATION OF KERNEL SIZE IN FLAX TO THE PERCENTAGE OF FRACTURED KERNELS IN THE SEED

Source of seed	Percentage of fractured kernels							
	1940 seed				1941 seed			
	Large kernels		Small kernels		Large kernels		Small kernels	
	Royal	Bison	Red-wing	Goss-amer	Royal	Bison	Red-wing	Goss-amer
Nappan, N.S.	32	20	25	—	0	0	0	—
Morden, Man.	83	62	45	60	36	41	12	28
Brandon, Man.	49	35	41	15	5	25	12	3
Melfort, Sask.	57	68	52	48	10	15	0	4
Swift Current, Sask.	65	78	70	90	28	28	15	34
Scott, Sask.	59	56	54	62	56	58	62	—
Lethbridge, Alta.	79	39	56	53	50	48	47	34
Lacombe, Alta.	24	27	21	14	22	23	19	29
Beaverlodge, Alta.	81	92	66	70	28	28	23	0
Mean*	58.7	53.0	47.7	47.7	26.1	29.5	21.1	18.8
Mean†	55.8		47.7		27.8		19.9	

* Mean of stations.
† Mean of large-seeded and small-seeded varieties.

Effect of Soil Type and Soil Temperature on Germination of Fractured Flax Seed under Greenhouse Conditions

Flax has been grown in Western Canada reasonably successfully on a wide variety of soils. Ordinarily, however, farmers have found it advantageous to plant less seed per acre on light soils than on heavy soils. This, in part, was due to the fact that flax seed seemed to germinate better in light than in heavy soils.

One of the reasons for the better germination in light soils seems to be that fractured flax seed is less likely to decay in light soil than in heavy soil. When, during this investigation, 30 different lots of flax seed were planted in each of four different soils, it was found (Table 5) that fractured seed, when treated, germinated equally well in all four soils; but, with untreated seed, the percentage germination decreased with each increase in soil density.

Treated, fractured seed appeared to germinate equally well in a range of temperature from 10° C. to 30° C. (Table 6), but the rapidity of germination was highest at 30° C. In untreated seed, the percentage of kernels germinating increased progressively up to 25° C. but fell off at 30° C. However, any differences in germination of treated and untreated seed observed between different soil temperatures were not statistically significant.

TABLE 5.—PERCENTAGE GERMINATION IN TREATED AND NON-TREATED, FRACTURED FLAX SEED PLANTED IN FOUR DIFFERENT SOILS

Soil type	Seed treatment	
	Treated	Control
Brown, sandy loam	92.1	56.7
Grey-wooded loam	91.6	50.9
High-lime black loam	94.7	44.0
Black clay loam	93.8	39.0
Necessary difference (5% level)	3.24	3.24

TABLE 6.—PERCENTAGE GERMINATION IN FRACTURED FLAX SEED SOWN IN BLACK, CLAY-LOAM SOIL HELD AT 5 DIFFERENT TEMPERATURES

Temperature	Seed treatment	
	Treated	Control
10° C.	94.5	44.7
15° C.	95.0	47.0
20° C.	97.5	49.7
25° C.	94.7	54.7
30° C.	96.7	50.0
Necessary difference (5% level)	D.N.S.*	D.N.S.

* D.N.S. = Differences not significant.

EFFECT OF THRESHING-INJURY ON SEED GERMINATION AND CROP YIELD UNDER FIELD CONDITIONS

In the majority of the Winnipeg experiments with flax, the percentage of seed germinating in the field was approximately the same as it was in the greenhouse, or it was somewhat higher. However, while a greenhouse test made at Winnipeg indicated fairly well how fractured flax seed would germinate under field conditions at Winnipeg, it did not necessarily indicate how the fractured seed would germinate under field conditions elsewhere. To determine what information regarding this point could be expected from a greenhouse test, 8 lots of Redwing flax, each containing a different percentage of fractured kernels, were planted in 1942 in the greenhouse at Winnipeg and at several experimental stations in Western Canada. The results from these trials are summarized in Table 7. They show that, at Winnipeg, as at most of the other stations, severely fractured flax seed germinated somewhat better in the field than it did in the greenhouse. The germination results were based on a comparison of the germination of

untreated, fractured seed with that of treated, uninjured seed, the latter being sown in plots in another part of the same experiment. The yield results were obtained in the same way, the yield of the plots sown with untreated, fractured seed being taken as a percentage of the yield of other plots sown with treated, uninjured seed.

The yield data from the field experiments just discussed were relatively inconclusive. Earlier (3), it was observed that moderate and severe fracturing of the seed definitely reduced the yield. In the present experiments, however, threshing-injury to the seed reduced the yield at some stations but not at others. An inspection of the plots at Winnipeg, Morden, and Brandon revealed that, in plots where there were thin stands of seedlings, the individual plants branched very freely. The result was that the yield from such plots was almost as large as the yield from plots with much denser stands of seedlings. Evidently, in plots with thin stands, the loss of seedlings resulting from seed fracturing was almost compensated for by increased branching of the surviving plants. It is not known how often such conditions occur in Western Canada, but it may be that crop losses from threshing-injury to the seed are generally less severe than indicated by earlier experiments (3).

TABLE 7.—GERMINATION OF UNTREATED, FRACTURED FLAX SEED IN NON-STERILE SOIL IN A GREENHOUSE IN RELATION TO ITS GERMINATION UNDER FIELD CONDITIONS AND TO THE SUBSEQUENT YIELD

Effect of kernel fracturing		Percentage of fractured kernels in seed							
		2	8	16	20	26	33	39	51
Germination in greenhouse, %		98	88	89	81	71	65	60	48
	Station								
Germination in field plots, %*	Winnipeg	94	96	87	88	82	82	85	65
	Morden	83	81	77	82	67	60	54	49
	Brandon	84	82	89	84	73	79	75	55
	Indian Head	100	100	100	100	100	100	97	83
	Melfort	81	80	92	84	80	81	68	63
	Swift Current	100	100	100	100	84	81	67	47
	Scott	—	—	—	—	—	—	—	—
	Lethbridge	98	93	91	94	79	77	76	54
	Lacombe	93	88	88	79	78	75	77	63
	Beaverlodge	89	91	81	75	71	77	72	56
	Mean of stations	91	90	89	87	79	79	74	59
Yield in field plots, %*	Winnipeg	100	98	99	100	98	96	96	93
	Morden	90	93	100	98	95	93	93	87
	Brandon	97	99	99	100	96	95	95	97
	Indian Head	100	76	96	100	100	100	100	82
	Melfort	100	96	100	100	100	96	93	90
	Swift Current	89	100	100	100	92	100	90	59
	Scott	91	81	99	77	86	100	77	71
	Lethbridge	84	87	86	88	89	79	87	85
	Lacombe	100	100	100	100	100	100	100	100
	Beaverlodge	92	100	98	97	100	81	94	89
	Mean of stations	94	94	97	96	95	94	92	85

* Germination of untreated, fractured flax seed in field plots and the subsequent yield expressed as a percentage of the average germination and yield in 6 plots in another part of each experiment but sown with treated, uninjured seed.

RESULTS FROM TREATMENT OF FRACTURED FLAX SEED

Comparison of Seed Disinfectants

Limitation of space in the greenhouse prevented a comparison of many seed disinfectants simultaneously on a large scale. On this account, a greenhouse test usually consisted of duplicate plantings made at different times. In the field, where more space was available, each treatment was replicated at least six times.

TABLE 8.—EFFECT OF DIFFERENT DOSAGES OF VARIOUS SEED DISINFECTANTS ON THE PERCENTAGE GERMINATION OF FRACTURED FLAX SEED UNDER GREENHOUSE AND FIELD CONDITIONS AND ON THE SUBSEQUENT YIELD IN FIELD PLOTS

Seed disinfectant	Dosage (oz. per bu.)	Germination, %						Yield‡, gm.		
		Greenhouse†			Field‡					
		1941	1942	1943	1941	1942	1943	1941	1942	1943
Control	0.0	56.6	45.0	43.0	167.5	262.1	249.0	111.4	218.0	91.2
N.I. Ceresan*	0.5	69.2	59.5	75.5	186.1	293.8	368.2	116.5	210.9	132.0
N.I. Ceresan*	1.0	—	84.5	93.5	—	367.0	372.5	—	202.2	112.7
N.I. Ceresan*	1.5	88.9	88.5	93.5	203.1	394.8	404.5	111.7	205.9	150.7
N.I. Ceresan*	2.0	—	91.0	91.5	—	306.8	397.7	—	209.5	129.7
Half-ounce Leytosan	0.5	58.7	47.0	59.5	183.1	293.5	299.0	114.7	210.7	116.7
Half-ounce Leytosan	1.0	—	50.5	73.0	—	278.3	345.0	—	196.1	126.7
Half-ounce Leytosan	1.5	76.4	76.5	75.0	202.1	306.8	345.7	125.0	208.1	108.5
Half-ounce Leytosan	2.0	—	75.0	89.0	—	319.0	355.0	—	196.6	135.5
Leytosan	1.0	64.0	—	—	174.0	—	—	113.1	—	—
Leytosan	4.0	77.5	—	—	197.0	—	—	113.3	—	—
Lunasan	0.5	52.0	—	—	178.4	—	—	113.8	—	—
Nomersan	7.0	64.5	—	—	185.9	—	—	112.4	—	—
Spergon	1.0	—	48.0	58.0	—	278.6	281.0	—	218.8	119.2
Spergon	2.0	—	41.0	61.5	—	271.5	309.2	—	205.0	110.7
Spergon	3.0	—	58.5	68.5	—	294.8	313.2	—	190.7	106.0
U.S.R. 601††	1.0	—	46.0	48.0	—	224.0	250.7	—	195.0	113.2
U.S.R. 601	2.0	—	39.5	48.0	—	266.6	220.5	—	203.2	104.0
U.S.R. 601	3.0	—	38.5	49.5	—	259.6	234.0	—	190.2	103.5
U.S.R. 604	1.0	—	73.0	68.5	—	266.1	371.7	—	190.5	117.7
U.S.R. 604	2.0	—	83.0	85.0	—	247.5	361.7	—	201.0	131.5
U.S.R. 604	3.0	—	82.0	85.0	—	245.6	356.0	—	195.9	114.0
Thiosan	0.5	—	45.5	—	—	203.8	—	—	195.5	—
Thiosan	1.0	—	47.5	80.0	—	255.1	352.2	—	203.3	114.7
Thiosan	1.5	—	57.0	—	—	264.8	—	—	207.9	—
Thiosan	2.0	—	65.0	87.0	—	279.0	341.5	—	209.2	118.0
Thiosan	3.0	—	—	89.0	—	—	280.7	—	—	91.2
Arasan	1.0	—	—	84.5	—	—	364.7	—	—	133.2
Arasan	2.0	—	—	91.0	—	—	402.2	—	—	121.0
Arasan	3.0	—	—	91.5	—	—	377.7	—	—	119.2
Necessary difference (5% level)		—	—	—	16.7	47.6	43.7	D.N.S.§	7.6	4.7

* New Improved Ceresan.
† Percentage germination (means of 2 replicates).
‡ Count of mature plants and yield in 10′ 0″ row.
§ D.N.S. = Differences not significant.
†† United States Rubber Co.

The results obtained from a comparison of different seed disinfectants, in respect to their effect on germination of fractured flax seed and the subsequent yield, are summarized in Table 8. These results indicate that New Improved Ceresan, Half-ounce Leytosan, Leytosan, U.S.R. 604, Thiosan, and Arasan satisfactorily prevented the rotting of fractured flax

seed in non-sterile soil in the greenhouse. Nomersan, Spergon, and U.S.R. 601 were less effective. Under the field conditions prevailing at Winnipeg in 1941, New Improved Ceresan, Half-ounce Leytosan, and Leytosan significantly increased the stand of plants but they failed to increase the yield. In 1942, New Improved Ceresan and Half-ounce Leytosan again significantly increased the stand of plants but failed to increase the yield, and in that year the plots sown with untreated seed yielded more than did the plots sown with seed treated with most of the disinfectants tried. In 1943, the stand of plants was significantly improved when the seed was treated with New Improved Ceresan, Half-ounce Leytosan, Spergon, U.S.R. 604, Thiosan, and Arasan; and the increases in density of stand were followed by increases in yield. The results from these experiments indicated that the two mercury-containing seed disinfectants, New Improved Ceresan and Half-ounce Leytosan, gave the best results when used at the rates of $1\frac{1}{2}$ oz. and 2 oz., respectively, per bushel of seed.

In addition to the experiments that were made at Winnipeg, field experiments with treated and untreated, fractured and sound flax seed were made at nine other stations in 1942 and at eight other stations in 1943. In each year, New Improved Ceresan was applied to the seed at

TABLE 9.—EFFECT OF TREATING SOUND AND FRACTURED FLAX SEED WITH NEW IMPROVED CERESAN (1.5 OZ. PER BU.) ON NUMBER OF PLANTS IN A 10 FT. ROW, AND ON THE RESULTING YIELD

Year	Station	Number of plants					Yield (gm.)				
		Sound seed		Injured seed		Necessary difference (5% level)	Sound seed		Injured seed		Necessary difference (5% level)
		Treated	Control	Treated	Control		Treated	Control	Treated	Control	
1942	Winnipeg	332	312	235	216	44.5	157	159	154	147	D.N.S.
	Morden	393	330	257	194	78.8	123	112	111	108	D.N.S.
	Brandon	379	319	285	208	D.N.S.*	143	139	144	138	D.N.S.
	Indian Head	437	468	399	361	D.N.S.*	166	169	146	136	24.6
	Melfort	350	285	313	220	D.N.S.*	119	119	116	108	D.N.S.
	Swift Current	64	81	79	30	22.4	81	72	88	48	D.N.S.
	Scott	—	—	—	—	—	107	98	95	77	D.N.S.
	Lethbridge	349	344	302	188	D.N.S.	203	171	163	173	D.N.S.
	Lacombe	412	386	291	261	D.N.S.	178	179	175	191	D.N.S.
	Beaverlodge	434	385	287	242	D.N.S.	266	246	260	236	D.N.S.
	Mean	350	323	272	213		154	146	145	136	
1943	Winnipeg	352	384	274	114	33.0	103	110	100	86	13.2
	Morden	291	322	212	165	31.4	90	98	85	91	D.N.S.
	Brandon	393	420	318	283	41.7	120	120	118	118	D.N.S.
	Indian Head	442	433	399	348	25.1	105	105	97	101	D.N.S.
	Melfort	418	387	364	288	D.N.S.	87	90	84	81	D.N.S.
	Swift Current	267	262	218	125	32.5	52	53	49	40	D.N.S.
	Scott	288	274	265	225	D.N.S.	76	79	90	77	D.N.S.
	Lethbridge	411	402	353	306	D.N.S.	154	143	146	140	D.N.S.
	Beaverlodge	343	328	246	156	27.6	100	102	88	73	8.8
	Mean	356	356	294	223		98	100	95	89	

* D.N.S. = Differences not significant.

the rate of 1½ oz. to a bushel. It was found (Table 9) that, notwithstanding a considerable variability between stations and between plots at a station, there was a general tendency for this treatment to increase the stand of plots sown with fractured seed. In several of the trials, however, the increases were too small to be statistically significant. In all the trials, there was little or no increase in density of stand when the treatment was applied to uninjured seed. The experimental results regarding yields (Table 9) were even less conclusive. The plots sown with treated, fractured seed tended to yield more than those sown with untreated, but in most of the trials the difference was not statistically significant. In 1/100-acre plots (Table 10) treatment of flax seed with New Improved Ceresan increased, in 1941, the stand of plants and the yield in proportion to the degree of seed injury, but the increase was less at Winnipeg than at Morden. In 1942, however, when a similar experiment, but with other lots of seed, was carried on at Winnipeg, Morden, and Brandon, seed treatment neither increased the stand nor increased the yield.

Effect of Excessive Dosages of Seed Disinfectants

Preliminary experiments carried on in the greenhouse during 1941 showed that when an excess of New Improved Ceresan (all the dust the seed could retain) was added to the seed, germination of the seed was retarded, the seedlings frequently possessed enlarged cotyledonary leaves, and, in some seedlings, no other leaves were formed. When Half-ounce Leytosan was applied to the seed in excess, germination was not retarded, but the seedlings became somewhat chlorotic and the rate of growth in the post-seedling stage was reduced. It was subsequently found that the degree of chlorosis was proportional to the dosage of dust applied to the seed. Spergon, in excess, did not retard germination of the seed, but after the seedlings had formed a few leaves a peculiar cup-like structure developed at the apex of each plant. This malformation resulted apparently from a fusion of several embryonic leaves. It had no adverse effect on the plant, as the stem continued its growth through the cup. This post-seedling effect of Spergon has recently been described by Forsyth and Schuster (1).

TALBE 10.—EFFECT OF TREATING LOTS OF FLAX SEED, CONTAINING DIFFERENT PERCENTAGES OF FRACTURED KERNELS, WITH NEW IMPROVED CERESAN (1.5 OZ. PER BU.) ON THE STAND OF PLANTS AND THE YIELD IN 1/100 ACRE FIELD PLOTS

Year	Station	Increase in germination over untreated controls, %				Increase in yield over untreated controls, %			
		Lot 1	Lot 2	Lot 3	Lot 4	Lot 1	Lot 2	Lot 3	Lot 4
1941*	Laboratory	41.0	91.0	174 0	—	—	—	—	—
	Winnipeg	17.1	33.0	38.9	—	0.0	6.0	12.5	—
	Morden	38.0	85.0	92.2	—	20.0	33.5	45.5	—
1942	Laboratory	0.0	4.6	62.5	104.4	—	—	—	—
	Winnipeg	29.5	7.4	18.6	1.5	0.0	10.5	14.4	14.8
	Morden	55.8	0.0	97.2	0.0	2.0	4.0	2.6	0.0
	Brandon	13.8	13.8	5.4	9.2	2.9	2.5	0.0	0.0

* The seed used in 1941 was different from that used in 1942.

The effect of excess dosages of different seed disinfectants on germination and yield of flax under field conditions was studied in 1941 and 1942. New Improved Ceresan delayed seed germination and seedling growth, but seed treatment with Half-ounce Leytosan had no visible adverse effect. Seedlings arising from seed treated with Spergon developed apical cups, the stem internodes were lengthened, the branches developed a somewhat prostate habit of growth, and blossoming was retarded by more than a week.

The experimental results given in Table 11 show that when an excess of undiluted New Improved Ceresan or Half-ounce Leytosan was applied to fractured seed of Redwing flax, the stand of plants in 1941 was less dense than when either dust was first diluted and then applied in excess to the seed. With Bison flax, an excess dosage of undiluted Half-ounce Leytosan reduced the stand of plants but a similar dosage of New Improved Ceresan did not; and, when the dusts were diluted, neither dust caused any harm to the seed. None of the dusts just mentioned had any effect on the yield. In 1942, when this experiment was repeated but only the variety Redwing was used, excess dosages of undiluted or diluted New Improved Ceresan and Half-ounce Leytosan, and undiluted Spergon, failed to affect either the stand or the yield.

TABLE 11.—EFFECT OF DIFFERENT DUST SEED DISINFECTANTS, APPLIED TO FRACTURED FLAX SEED IN EXCESS *, ON THE NUMBER OF PLANTS IN A PLOT AND THEIR SUBSEQUENT YIELD

Disinfectant	Dilution†	1941				1942	
		Redwing		Bison		Redwing	
		No. of plants	Yield, gm.	No. of plants	Yield, gm.	No. of plants	Yield, gm.
Control	—	165	123	157	111	286	181
New Improved Ceresan	0	228	130	208	131	305	190
New Improved Ceresan	1–1	249	131	194	123	313	170
New Improved Ceresan	1–2	249	130	212	117	314	179
Half-ounce Leytosan	0	206	120	139	97	306	180
Half-ounce Leytosan	1–1	245	136	209	128	309	184
Half-ounce Leytosan	1–2	247	139	214	126	295	180
Spergon	0	—	—	—	—	302	184
Necessary difference, (5% level)	-	20.6	D.N.S.‡	20.6	D.N.S.	D.N.S.	D.N.S.

* Excess = maximum amount retained by seed.
† Dilution 1–1 = equal volumes of disinfectant and talc;
1–2 = 1 volume dust with 2 volumes of talc.
‡ D.N.S. = difference not significant.

Effect of Storage on Treated Flax Seed

The results of seed treatment experiments given earlier (Table 8), indicated that the optimum dosage for flax seed was $1\frac{1}{2}$ oz. per bushel with New Improved Ceresan and 2 oz. per bushel with Half-ounce Leytosan. These dosages were considerably larger than the dosages generally recommended by the manufacturer of the two respective dusts and it seemed advisable, therefore, to study the effect of storage on flax seed given these larger

dosages. In a preliminary experiment, sound seed of Redwing and Bison flax was treated with New Improved Ceresan and Half-ounce Leytosan at 1½ oz. and 2 oz. per bushel, respectively. Each lot of treated seed, as well as one untreated lot of each variety, was then divided into three portions, one of which was put into a glass jar, another into an ordinary grocers paper bag, and the third into a woven cotton bag. The jars and bags were then closed and all were placed in a dark room at a temperature ranging from 50° C. to 70° C. Samples of the stored seed were removed at intervals and planted, in duplicate, in a bed of non-sterile soil. The results from this preliminary experiment are given in Table 12 and they show that neither a 1½ oz. dosage of New Improved Ceresan nor a 2 oz dosage of Half-ounce Leytosan reduced germination of the sound seed, even after it was stored for 637 days in a sealed, glass container. Flax seed stored in paper or cloth bags appeared to lose some of its germinability, but the loss in treated seed could not be attributed to an overdose of either disinfectant.

TABLE 12.—EFFECT OF DIFFERENT KINDS AND LENGTHS OF STORAGE ON THE PERCENTAGE GERMINATION IN SOUND FLAX SEED TREATED WITH NEW IMPROVED CERESAN OR WITH HALF-OUNCE LEYTOSAN

Fungicide	Variety	Kind of Storage*	Duration of storage (days)						
			0	21	49	96	300	379	637
None	Redwing	A	92	92	96	95	94	88	97
		B	92	95	90	89	85	87	86
		C	92	97	93	94	95	87	86
	Bison	A	85	89	88	87	87	87	89
		B	88	82	84	81	79	88	82
		C	88	86	90	85	81	86	81
New Improved Ceresan†	Redwing	A	93	97	91	94	89	95	91
		B	97	91	95	91	93	90	89
		C	94	87	96	98	87	91	85
	Bison	A	87	92	85	90	90	89	92
		B	92	92	94	83	85	88	81
		C	89	86	87	89	96	90	91
Half-ounce Leytosan‡	Redwing	A	93	92	98	93	91	91	93
		B	90	91	94	93	87	83	86
		C	98	98	94	97	95	96	94
	Bison	A	88	81	86	88	86	84	90
		B	92	89	89	93	88	88	90
		C	92	89	92	89	88	88	78

* Storage A = sealed glass jar; B = paper bag; C = cloth bag.
† Applied at the rate of 1.5 oz. dust to a bu.
‡ Applied at the rate of 2.0 oz. dust to a bu.

In the spring of 1942, different seed disinfectants were applied to fractured seed of Bison flax and the several lots of treated seed, as well as one untreated lot, were put into glass jars which were sealed and placed in dark storage at room temperature. In the spring of 1943, these lots of stored seed were planted in the field, along with other lots of the same seed but treated shortly before sowing. The results from this experiment are given in Table 13. They show that when fractured seed was treated with

New Improved Ceresan, Half-ounce Leytosan, or Spergon, and then stored, some injury to the seed from the disinfectant resulted. The injury, however, was not severe enough to cause an appreciable reduction in yield. When flax seed was treated with U.S.R. 601, U.S.R. 604, and Thiosan, storage cause no injury whatever.

In 1942, a number of different lots of Redwing flax, each containing a different percentage of fractured kernels, were left untreated or were treated with New Improved Ceresan at the rate of $1\frac{1}{2}$ oz. per bushel. Each of these lots was then divided into a number of sub-lots which were placed in paper coin-envelopes. A set of treated and untreated sub-lots was sent to each of several experimental stations in Western Canada for planting. A survey of the data from these plantings showed (Figure 4) that in both the treated and the untreated seed the percentage of kernels germinating decreased as the percentage of them that were fractured increased. With treated seed, however, the percentage of kernels germinating was somewhat higher than with untreated seeds.

TABLE 13.—EFFECT OF STORAGE ON FRACTURED BISON FLAX SEED TREATED WITH VARIOUS DISINFECTANTS AND KEPT FOR ONE YEAR IN SEALED GLASS JARS AT ROOM TEMPERATURE

Fungicide	Dosage (oz. per bu.)	No. of plants in 10 ft. row		Yield, gm.	
		Seed A*	Seed B†	Seed A*	Seed B†
Control	0.0	141	138	140	136
New Improved Ceresan	0.5	229	201	155	145
New Improved Ceresan	1.0	224	289	152	152
New Improved Ceresan	1.5	276	317	166	156
New Improved Ceresan	2.0	260	329	155	157
Half-ounce Leytosan	0.5	224	197	152	144
Half-ounce Leytosan	1.0	169	189	149	143
Half-ounce Leytosan	1.5	215	247	158	159
Half-ounce Leytosan	2.0	238	227	144	147
Spergon	1.0	126	131	128	133
Spergon	2.0	155	174	131	146
Spergon	3.0	163	216	130	138
U.S.R. 601**	1.0	123	121	132	143
U.S.R. 601**	2.0	107	95	126	122
U.S.R. 601**	3.0	92	114	128	122
U.S.R. 604**	1.0	146	164	145	137
U.S.R. 604**	2.0	188	199	152	138
U.S.R. 604**	3.0	187	158	145	131
Thiosan	0.5	139	146	141	124
Thiosan	1.0	187	178	149	149
Thiosan	1.5	210	212	152	151
Thiosan	2.0	221	199	142	147
Necessary difference (5% level)††		55.4		19.1	
Mean		182	192	144	141
Necessary difference (5% level)		D.N.S.‡		D.N.S.	

* Seed treated in 1942 and sown in 1943.
† Seed treated in 1943 and sown in 1943.
** United States Rubber Co.
†† Applicable to any above pair of values.
‡ D.N.S. = Difference not significant.

The above situation is difficult to explain. In a greenhouse test made before the seed was sent out, all the lots of treated seed germinated alike, differences in severity of seed-fracturing notwithstanding. It was thought, at first, that the protectant on the seed had deteriorated to some extent. This belief arose as the result of observations on the behaviour of treated Laxton's Progress peas that had been kept in storage for some time. These peas, injured by threshing, had been treated at the rate of $1\frac{1}{2}$ oz. per bushel with New Improved Ceresan and were then stored in sealed glass jars or cloth bags for a period of ten months. At the end of this interval, the treated peas stored in sealed glass jars germinated 99% in non-sterile soil while those in cloth bags germinated only 15%. When, however, the latter lot of peas was treated again with New Improved Ceresan at the original rate, the percentage germination rose to 92%. The same result was obtained in each of several subsequent trials, and it suggested that New Improved Ceresan gradually lost its value as a seed protectant when exposed to air.

Later experiments with treated fractured flax seed failed to support the findings with peas. When treated and untreated flax seed was stored in sealed glass jars or in paper envelopes, and then after different intervals of time, some of the seed was removed and planted in non-sterile soil without additional treatment or after treatment (in some seed lots the second treatment) with New Improved Ceresan at the original rate, it was found (Table 14) that fractured flax seed suffered chemical injury after prolonged storage, but that there was no apparent decrease in the protection afforded by New Improved Ceresan to the seed.

TABLE 14.—EFFECT OF DIFFERENT INTERVALS OF STORAGE IN SEALED GLASS JARS AND PAPER COIN ENVELOPES ON THE PERCENTAGE GERMINATION OF TREATED AND UNTREATED FRACTURED FLAX SEED

Method of storage	Original treatment*	Additional treatment†	Storage interval (days)					
			0	12	25	51	98	342
Sealed jar	None	None	27.0	31.0	35.3	37.0	43.6	65.3
	None	New Imp. Ceresan	95.0	90.0	88.6	89.3	95.2	94.6
	New Imp. Ceresan	None	91.3	88.0	84.3	79.0	85.0	80.0
	New Imp. Ceresan	New Imp. Ceresan	91.6	91.0	84.6	74.0	86.8	74.6
Paper envelope	None	None	30.0	26.0	47.0	32.3	38.2	60.6
	None	New Imp. Ceresan	92.6	90.0	88.6	90.6	95.2	92.3
	New Imp. Ceresan	None	91.6	88.0	84.3	83.0	82.2	83.7
	New Imp. Ceresan	New Imp. Ceresan	95.0	82.7	87.0	84.0	86.9	81.3

* Dust applied at the rate of 1.5 oz. of dust to a bushel of seed.
† Dust applied at the rate used in previous treatment.

Although the above experiments with fractured peas and fractured flax seed yielded opposing results, it would seem that both results help to explain the situation (Figure 4) observed when treated flax seed was planted at different experimental stations in Western Canada. This situation could be the result either of a partial loss of protection afforded the seed by a disinfectant or an injury from the disinfectant to fractured seed. With a loss of protection, the percentage of kernels rotting in soil would increase with an increase in the percentage of fractured kernels;

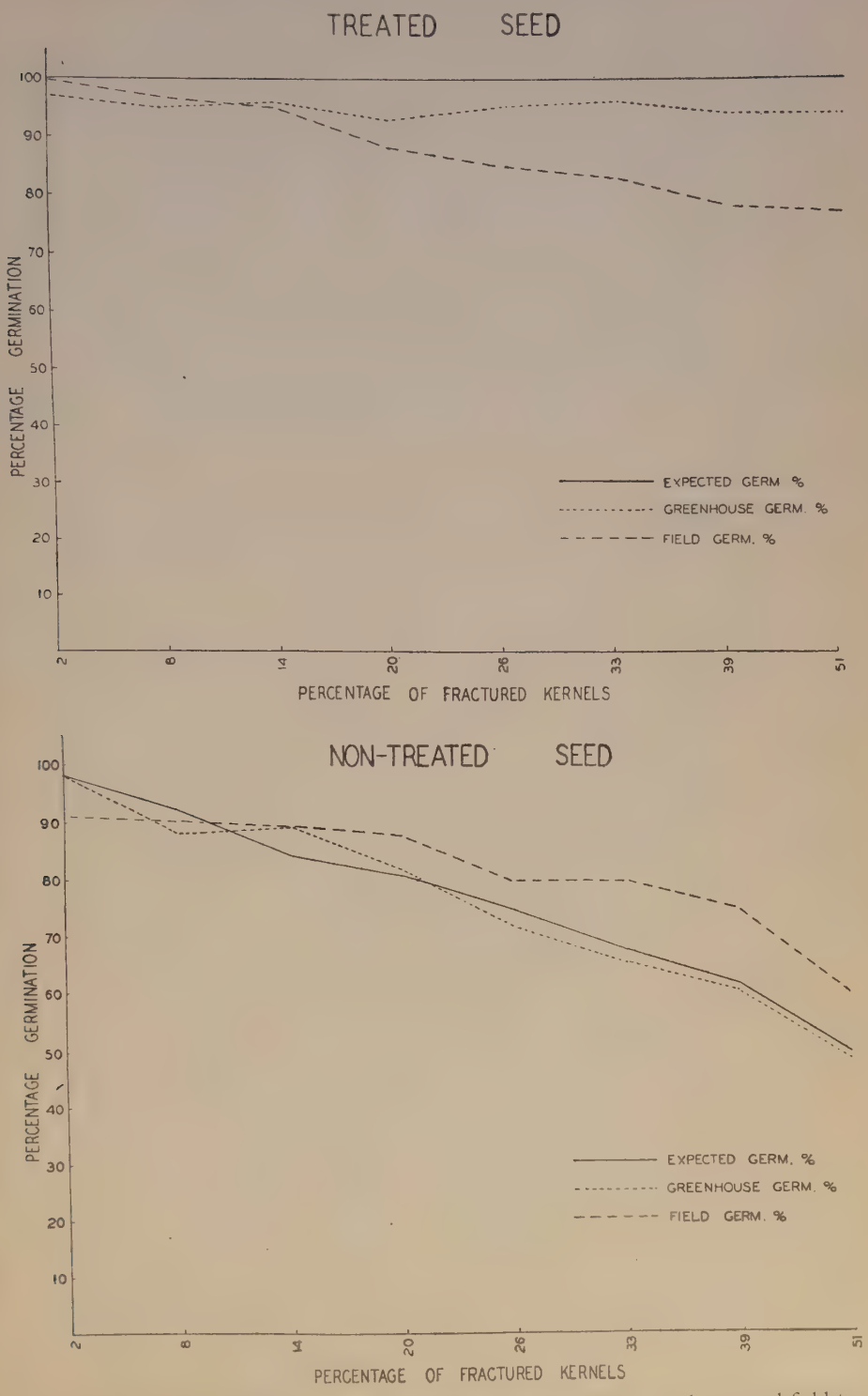


FIGURE 4. Relation of actual percentage germination in greenhouse and field to the expected germination. Above: treated seed. Below: non-treated seed.

while, with injury from the disinfectant, the percentage of seeds germinating would decrease with an increase in the percentage of fractured kernels. Possibly, both factors may operate simultaneously.

In passing, it may be worth while drawing attention to the fact that fractured flax seed appeared to become decreasingly susceptible to rotting in soil when such seed was stored for a period of time previous to planting. The experimental results (Table 14) with untreated seed stored in sealed glass jars show this tendency. It is suggested that, in fractured living kernels of flax, the exposed walls of fissures may, under suitable conditions of storage, gradually undergo a healing process through the development of cork or callus tissue. If this supposition is correct, soil-borne, seed-rotting organisms may be debarred entrance into the tissues of fractured kernels. The cotyledons are merely parts of a dormant plant, and possibly the development of protective wound tissue, such as occurs in wounded dormant tubers of the potato, actually takes place.

Relation of Rate of Seeding to the Results Obtained from Seed Treatment

In Western Canada, flax has been sown at several rates of seeding, the rate generally being determined by the variety of flax used or by local conditions of soil and climate. These rates of seeding, ranging from 20 to 40 lb. to the acre, were established before threshing-injury to flax seed became recognized as a problem, and were, therefore, based on the results obtained locally with untreated seed. In view of the fact that seed treatment tended to increase the percentage germination in fractured flax seed, it seemed probable that treated flax seed would give satisfactory yields at rates of seeding lower than those used for untreated seed. To determine what these new rates of seeding actually were, several different lots of Redwing flax with a different percentage of fractured kernels in each lot were sown, treated and untreated, at Winnipeg in 1942 and 1943 at five different rates of seeding. The results of the experiment are given in Table 15. They show that the average yield of plots sown with the most severely fractured, untreated seed at the lowest rate of seeding, was not much below the average yield of plots sown with uninjured, treated seed sown at higher rates of seeding. As a matter of fact, seed treatment in this experiment could not be said to have increased the yield at all. An examination of the experimental data revealed a probable reason for this result. It was found that the number of plants, whether from treated or untreated seed, in a plot usually decreased with an increase in the percentage of fractured kernels in the seed. In plots sown with untreated seed, this decrease in the number of plants could be attributed to a rotting of fractured seed in soil, but, in the plots sown with treated seed, no rotting would take place, and, therefore, the reduction in the number of plants could be attributed only to a poisoning of fractured kernels by the fungicide. This toxic action of the fungicide evidently occurred in the interval (26 days) between treatment of the seed and the actual seeding, for, in greenhouse tests with freshly-treated seed, the most severely fractured seed germinated better than 90%. As a result of this progressive decrease in germination under field conditions, the difference in germination between treated and untreated seed was not sufficiently large at all the levels of seed fracturing studied to result in an observable difference in yield.

RECOMMENDATIONS GIVEN TO FARMERS REGARDING THE HANDLING OF THRESHING-INJURED SEED

During the course of this investigation, many samples of flax seed were received from farmers who wanted to know whether or not their flax seed was satisfactory for seed purposes. With the knowledge that seed treatment frequently improved the germination of seed in the soil, the writers set up a provisional classification based on the assumption that if 90% of the kernels in a sample germinated when planted in soil a satisfactory crop would result. Thus, for samples having a percentage germination of 90% or above, no treatment was deemed necessary. For samples which, after treatment, germinated below 90%, the usual rate of seeding was adjusted upward (see footnote under Table 16). For samples which germinated 90% or more when treated, and in which there was a gain of 20% or more in seed germination as the result of treatment, treatment of the seed with an organic mercury dust was recommended. Samples that, when treated, germinated less than 50% were regarded as unfit for seed purposes.

TABLE 15.—RELATION OF DIFFERENT RATES OF SEEDING AND OF DIFFERENT PERCENTAGES OF FRACTURED KERNELS IN THE SEED TO THE GERMINATION AND YIELD OF TREATED AND UNTREATED SEED OF REDWING FLAX

Rate of seeding (lb. per acre)	Fractured kernels, %	No. of plants per 10 ft. row				Yield, gm.				Yield increase from treatment, %	
		1942		1943		1942		1943			
		Treated	Control	Treated	Control	Treated	Control	Treated	Control	1942	1943
32	0	499	475	542	604	168	173	134	125	0	7
	20	406	405	547	493	156	166	136	130	0	4
	40	423	316	514	373	157	157	138	144	0	0
	60	366	286	491	324	156	156	116	130	0	0
28	0	458	403	546	524	162	151	141	127	7	11
	20	365	404	487	432	157	168	140	137	0	2
	40	363	310	451	339	167	163	131	153	2	0
	60	367	267	446	243	159	154	115	124	3	0
24	0	377	337	512	462	148	149	145	135	0	7
	20	408	313	461	398	168	154	134	145	16	0
	40	326	271	458	297	166	161	147	144	3	2
	60	275	243	380	234	148	148	136	127	0	7
20	0	326	345	386	353	146	156	130	141	0	0
	20	268	248	339	335	148	137	134	135	8	0
	40	277	243	339	243	161	151	141	135	7	4
	60	260	201	310	197	159	142	123	124	13	0
16	0	305	250	350	312	151	157	143	131	0	9
	20	258	217	337	217	138	148	134	135	0	0
	40	235	168	311	203	159	141	133	126	13	6
	60	198	182	280	148	148	136	110	113	9	0
Necessary difference (5% level)*		64.0		49.5		18.9		17.9		—	

* Applicable to any above pair of values.

In order to test the validity of the provisional classification just mentioned, 20 seed samples were taken from among those tested in the greenhouse, and, after the recommended adjustments were made, the seed was planted in the field at Winnipeg. One of these seed samples required no adjustment, 1 required an increase in the rate of seeding, 7 required treatment, and 11 required treatment and an increase in the rate of seeding. After the plants were harvested and threshed, the experimental data were examined to determine whether or not the original recommendations regarding the individual seed samples were justified. It was found (Table 16) that with all the seed samples used in the field test, except the one requiring no adjustment, the number of plants in a plot sown with adjusted seed was significantly greater than the number of plants in plots sown with unadjusted seed. A significant increase in yield was obtained, however, only in three (Nos. 9, 13, 16) of the 19 seed samples requiring adjustment, while, in 11 others the increase was not significant and, in the remaining 5 seed lots, there was no increase.

TABLE 16.—RESULTS FROM FIELD TESTS WITH SEED SAMPLES OF FLAX ADJUSTED IN THE WAY RECOMMENDED TO THE FARMERS IN ORDER TO COMPENSATE FOR KERNEL-FRACTURING OR NATURAL LOW GERMINABILITY OF THE SEED

Seed sample	Germination in greenhouse		Recommendations to farmers		Field results					
					No. of plants in 10 ft. row			Yield (gm.) from 10 ft. row		
	Treated	Control	Treat	Increase seeding rate by†	Adjusted	Control	Increase, %	Adjusted	Control	Increase, %
				%						
1	95	59	Yes	0	297	184	61.4	155	138	12.3
2	92	65	Yes	0	319	249	28.1	148	166	0.0
3	95	74	Yes	0	353	276	27.8	87	106	0.0
4	70	35	Yes	43	321	120	167.5	131	114	14.9
5	96	56	Yes	0	405	224	80.8	124	105	18.0
6	92	60	Yes	0	284	206	37.8	140	142	0.0
7	84	44	Yes	19	332	152	118.4	147	146	0.6
8	87	54	Yes	15	401	228	75.8	97	93	4.3
9	77	59	Yes	30	356	131	171.7	142	113	25.6
10	80	67	Yes	25	402	165	143 6	139	133	4.5
11	88	78	Yes	13	367	173	112.1	156	144	8.3
12	97	97	No*	0	418	371	12.6	159	158	0.6
13	71	57	Yes	41	304	103	195.1	150	126	19.0
14	84	68	Yes	19	290	95	205.2	135	112	20.5
15	86	65	Yes	16	386	264	46.2	89	84	5.9
16	82	57	Yes	22	366	94	289.3	146	113	29.2
17	79	72	No	39	345	224	54.0	92	94	0.0
18	70	57	Yes	43	386	125	208.8	106	87	21.8
19	94	73	Yes	0	383	238	60.9	82	90	0.0
20	99	54	Yes	0	388	298	30.2	149	152	0.0
Necessary difference (5% level)‡					48.7		—	24.0		—

* This undamaged seed sample was treated even though it was sound, to provide a comparison with damaged seed lots.

† Percentage increase in rate of seeding = $\frac{\%\text{ kernels not germinating}}{\%\text{ kernels germinating}} \times 100$.

‡ Applicable to any above pair of values.

It is evident from the results of the above test that the provisional classification of flax seed samples was not set up on a practical basis. It appears, as other experimental results in this paper have indicated, that in Western Canada, flax seed of relatively low germinability may produce as high a yield as can seed of high germinability sown at the same rate. On this account, the provisional classification of seed samples probably should have been set up on the assumption that flax seed, germinating 75 or 70%, or less, can produce a satisfactory crop, providing that the rate of seeding remains at the present level. It is unreasonable to recommend to farmers that they treat their flax seed or increase the rate of seeding when the gain in density of stand is not sufficiently large to be followed by a gain in yield.

DISCUSSION

From the evidence given in this paper, it would appear that threshing-injury to flax seed is widespread in Western Canada and that, unless the seed is properly treated, lowered germination results. Other evidence indicates, however, that usually such lowered germination is seldom followed by reduced yields. Any one of two or more factors seems to be responsible for this situation. The prime factor seems to be the ability of flax plants in thin stands to branch freely. Thus, in a thin stand of plants, the production of seed bolls may be as great per unit area as in a denser stand where the individual plants, on account of competition for nutrients, branch less freely. In consequence, when two plots of flax differ in density of stand, because one was sown with sound seed and the other was sown with seed damaged by threshing, by an injurious fungicide, or by other factors reducing the percentage of kernels germinating, the difference in stand is not necessarily accompanied by a difference in yield. A secondary factor seems to be the tendency for farmers to sow flax at a rate high enough to offset low germination of the seed. On this account, when good seed or seed that has been improved by seed treatment is sown at the rate used ordinarily, more plants than can be adequately nourished are produced. Owing to severe competition, the plants yield individually less than they would if they were more widely spaced, and, therefore, the yield is not likely to be any greater than that from poorer and untreated seed sown at the same rate.

During the course of greenhouse and field experiments with flax seed treated with Spergon or Half-ounce Leytosan, it was observed that these materials, when applied in large dosages, affected flax seedlings in a way different from that when the seed was treated with a heavy dosage of New Improved Ceresan. With the latter material, germination of the seed was retarded and frequently the seedlings failed to develop other than cotyledonary leaves; but with Half-ounce Leytosan and Spergon, the effect of the treatment became visible only after the flax seedlings had developed several leaves, that is, at the post-seedling stage. Half-ounce Leytosan caused some chlorosis in the leaves and stems, while Spergon caused "freak" plant structures and a change in the habit of growth. It has been commonly believed that when a disinfectant is applied to seed the effect of the disinfectant is directly on the seed. The above observations regarding Half-ounce Leytosan and Spergon show that the influence of disinfectants applied to seed may be carried on to the seedlings. While,

with the two seed disinfectants just mentioned, treatment of the seed has an adverse effect on the resulting seedlings, it is possible that treatment of the seed with other materials may have an effect beneficial to the resulting plants. These plants, besides being improved in health, may acquire some characteristic increasing their productivity. It would seem that the post-seedling effect of seed disinfectants and other chemicals would be a subject of fruitful study.

Throughout this investigation, it was found difficult to account for marked variations in yield of flax from replicate plots, especially when these happened to be adjacent to each other. The experiments were ordinarily placed on apparently uniform blocks of land, but some unknown influence caused large differences in yield. Such variations in yield resulted in a large experimental error that frequently made differences between plots statistically insignificant. It is possible that increased replication or the use of another experimental design would have improved the situation.

In view of the fact that, in the majority of the present experiments, flax seed was sown in rows spaced 12 inches apart, the experimental results obtained here may not be applicable under the conditions of seeding on an ordinary farm. In actual practice, flax seed is drilled in rows that are 6 inches apart. Also, in experimental plots, weeds are generally not allowed to compete with crop plants while, on an ordinary farm, no attempt is made to destroy weeds except before the crop is planted. It is conceivable, therefore, that in experimental plots the development of flax plants would be much more luxuriant than under ordinary field conditions and that thin stands of plants, arising from damaged, untreated seed, would be more capable of giving a satisfactory yield. Thus, in experimental plots, a difference in the quality of seed may have no effect on the final yield, while, on the ordinary farm, where competition from weeds is allowed, flax plants in a thin stand may not be permitted to grow as well as they would if the field was free from weeds. On the ordinary farm, therefore, low quality seed would likely result in lowered yields, and high quality seed (providing a denser stand of plants and thereby withstanding competition from weeds) would likely result in satisfactory yields.

SUMMARY

In Canada, flax seed is often fractured when threshed during dry weather. This injury is much more common in Western Canada than in Eastern Canada. In some lots of seed, all the kernels may be fractured. The fractures are generally minute and invisible to the unaided eye, and, consequently, their presence does not affect the market grade of the seed. Large-seeded varieties of flax appear to be more subject than the small-seeded varieties to this type of injury.

When fractured flax kernels are planted in ordinary soil, many of them rot as a result of invasion by soil-borne micro-organisms. This rotting appears to be more frequent in heavy soils than in light soils, but the frequency of rotting does not seem to be affected by variation in soil temperature. When injured seed is planted under field conditions, the loss of plants from the rotting of fractured kernels is generally less severe than it is in the greenhouse.

Treatment of fractured kernels with suitable seed disinfectants prevents their decay in non-sterile soil. In heavy soils, New Improved Ceresan applied at the rate of $1\frac{1}{2}$ oz. per bushel gave the best result. In seed treated with New Improved Ceresan, prolonged storage may reduce the germination of fractured seed, but appears to cause no reduction in the germination of non-fractured seed. Treatment of flax seed with heavy dosages of Spergon may result in post-seedling damage to the plants.

While seed treatment generally improved the germination of fractured flax seed under experimental plot conditions, the improvement did not always result in improved yield. Similarly, when non-fractured seed was sown in the field, it germinated better than did fractured seed but the resulting yields were often at the same level.

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FIFTEEN YEARS EXPERIMENTS ON THE GRAY WOODED SOILS OF ALBERTA

By F. A. Wyatt[1]

University of Alberta, Edmonton, Alberta

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Wooded soils constitute one of the world's great soil groups and are found in all provinces of Canada. Practically the entire area east of the Great Lakes belongs to the wooded soil group. In the Prairie Provinces, the areas in the wooded soil group by far exceed the areas in the prairie soil groups. However, a much smaller proportion of the total wooded soils will be cropped than will be the percentage of cropped land in the prairie groups.

There are parts of the wooded soil areas in Ontario, Manitoba, Saskatchewan, Alberta, British Columbia and also in the North West Territories and in the Yukon that will be devoted to crops in the future. Alberta has a greater area of such soils than is found in any other province, and ultimately over 50% of all cropped lands in Alberta will belong to this group. For detailed descriptions of these soils, reference is made to Bulletin 21 (1), Circular 23 (2), and to some of the Soil Survey reports (3, 4). However, for convenience of the reader the following brief description might be adequate. These soils in Alberta belong to the gray wooded (northern podsolic) group and are characterized by the general profile descriptions:

Thickness of Horizon

0 – 4″	A_0 moss to leaf mould; absent where fires have been severe. pH varies from 4 to 7 +, usually 5.5 to 6.8.
0 – 4″	A_1 mineral soil with varying amounts of organic matter; brownish to black platy. pH varies from 4.5 to 7 usually from 5.5 to 6.7.
4 – 14″	A_2—average thickness 5 to 9″, light gray to grayish brown, platy and ashlike. pH varies from 4.5 to 7, usually from 5.5 to 6.7.
6 – 18″	B_1—average thickness about 12″, light grayish brown to brownish (influenced by parent material) but usually darker than A_2, pH varies from 5 to 7, usually 5.5 to 6.8, granular to nutty.
6 – 30″	B_2—average about 18″, sometimes lighter in colour than B_1. Structures not so well defined as in B_1. pH varies from 5.5 to 7 +.
18 – 60″	Bca—below surface.

When the virgin soils are first broken they have a very light gray appearance due to the exposed A_2 horizon. The furrow slice consists of A_0, A_1 and largely A_2 horizons. After several years of cultivation these horizons become mixed and the field then appears light grayish brown to light brown in colour. The pH of the cultivated fields (plow depth) varies from just over 5 to about 7. There is but little response to the application of lime and no difficulty is encountered in securing good stands of clovers and alfalfa, provided sulphur is applied when needed.

[1] Professor of Soils.

TABLE 1.—RANGE OF pH VALUES FOR SOILS FROM SOME OF THE BRETON PLOTS, SAMPLES COLLECTED 1940, 41 AND 44

Series A and C (Rotation)

Plot	1	2	3	4	5	6	7	8	9	10	11
Fertilizer applied	0	Manue	16–20–0 + K_2SO_4	Amm. sulphate	0	Lime	Lime + triple super	Triple super	Manure 16–20–0	16–20–0	0
Depth											
0 – 7″	5.7–6.6	5.9–6.9	5.2–6.5	5.4–6.6	5.9–7.0	6.9–7.5	7.0–7.7	5.9–7.3	6.2–7.3	5.4–6.9	5.9–7.0
7 – 18″	5.9–6.0	5.8–6.0	5.6–5.7	5.6–5.8	5.7–5.9	5.7–6.2	5.9–6.3	5.7–5.8	5.6–5.7	5.5–5.6	5.7–6.3
20 – 40″	5.9–6.0	5.7–6.0	5.5–5.9	5.6–5.8	5.8–6.0	5.6–5.9	5.7–6.0	5.6–5.7	5.6–5.7	5.5–5.6	5.8–5.9

Series E (Continuous wheat)

0 – 7″	6.6–6.7	6.8–6.9	6.5–6.6	6.5–6.6	7.0	7.4–7.5	7.5–7.6	7.0–7.1	7.2–7.3	6.6–6.9	6.4–7.0
7 – 18″	6.3–6.4	6.4	6.4	6.5	6.5	6.6–6.7	6.6–6.7	7.0	7.2	5.8–6.8	6.1–6.8
20 – 40″	6.0–6.1	6.0	6.2	5.8–5.9	6.1–6.2	5.9	6.1	6.4–6.5	6.6	5.6–6.0	5.6–6.0

A better idea of the range in pH values may be obtained by referring to the data from the plots from three of the series at Breton and reported in Table 1. These samples were collected from the same plots during three different years and in some instances at different intervals during the same years. The extreme ranges in pH values for the various plots are reported in the table. Here it is seen that the soil to the plow depth (0 to 7 inches) varies in pH values for the different samples collected. This variation is common to all plots and at times amounts to 1.5 pH units. The plow depth samples are generally just slightly acid ranging from just under 6 to just over 7 with the exception of plots 6 and 7 (limed) where the surface samples are at all times alkaline. There is no clear cut indications that any of the fertilizers (except lime) has influenced the pH values of the soils after 15 years of application (see Table 2 for annual rates).

The gray wooded soils of Alberta are found in the forested area. These forests consist chiefly of poplar, spruce, pine, willow, alder and tamarack, together with the common shrubs and sparse grasses. The rainfall over the greater part of the area varies from about 15 to 20 inches. However, the extreme northern part of the zone receives somewhat less rainfall, but even here there is generally a well developed soil profile in its upper horizons.

Any great expansion in the acreage of cropped land must of necessity take place on the wooded soils. Some of the problems involved in the future use of these wooded soils are:

(a) With proper management of these wooded soils, are they capable of producing satisfactory yields?

(b) What crops can and must they produce in order to maintain a satisfactory level of yields?

(c) How would extensive development of these soils affect the economy of Canadian agriculture?

(d) How would such development affect the health and wealth of the farming population?

(e) What would be the effect on land values?

The first two of the above questions can be definitely answered in the affirmative from our experiments on the wooded soils. The results from numerous co-operative experiments with individual farmers together with the results secured from the Breton Experimental plots during the past fifteen years show that, with proper management, it is possible to produce from 35 to 40 bushels of wheat, as the first crop after clover, from 60 to 80 bushels of oats as the second crop after clover, and from 25 to 35 bushels of barley as the third crop after clover. The clovers and alfalfa after being nursed with barley, yielded from $2\frac{1}{2}$ to 3 tons per acre on the best plots. The above yields were secured when adequate rotations and management were followed and were from 2 to 4 times the natural initial production from the soil without rotations and without fertilizers. Such yields as those secured above compare favourably with yields from the most productive sections of the black soil areas.

For purposes of reference, it might be well to show the cropping practices, the arrangement of plots, the kinds and amounts of fertilizers applied, and only the average yields secured from the Breton plots during the past five years (1940-44). These data are listed below in Tables 2, 3 and 4 without showing much of the detail actually involved in the practical farming operations. It is sufficient to say that any farmer occupying similar soils could carry out all the operations now performed on the Breton plots.

PLAN OF THE BRETON PLOTS

These plots are located about 70 miles south-west of Edmonton on typical wooded soil. The field contains about 20 acres of which 18 acres are in plots and the remainder is devoted to borders and roadways. The field was laid out in plots in 1930. Originally there were only 16 plots in each series but in 1938 an additional 10 plots were added to each series. Plot 12 is used as a roadway, while of the other 25 plots in each series, 7 are used as checks and 18 receive applications of various fertilizers (See Table 2). During the 15-year period (1930-44), 15 crops of wheat, 15 of oats, 22 of barley, 3 of flax, 2 of peas, 46 of clovers and alfalfa have been grown in sequence in addition to 12 crops of wheat on Series E (continuous wheat, one-half being cropped and the other half fallowed). With the exception of flax and peas all other crops have been produced annually and have been subjected to the individual seasonal effects of 15 consecutive years. Thus the average yields may be considered as fairly reliable.

The experimental field consists of 6 full series of 25 plots each in addition to 3 series with fewer plots. Each full plot is 1/11 acre, being 30 ft. wide by 8 rods long. The total number of plots is just under 200. The series extend north and south and the plots east and west. The main rotation includes 5 series, illustrated as follows:

Series A—First year clovers (alfalfa and altaswede).

Series B—Second year clovers broken (the first cutting of hay is removed from the west half but the entire crop is plowed down on the east half).

Series C—Wheat—first crop after clovers.

Series D—Oats—second crop after clovers.

Series F—Barley—third crop after clovers (this crop nurses clovers to remain for next two years).

Series E is devoted to the continuous production of wheat, one-half being fallowed and the other half cropped each alternate year. Series G and H are used for the production of alfalfa and are only broken at intervals of 4 or 5 years. On several occasions flax, peas and barley have been grown after breaking alfalfa and clovers.

The crops are harvested and yields obtained from each plot and some half plots every year. Most of the crops are analyzed and graded annually. Baking tests for the wheat, malting tests for the barley, and oil content tests for the flax have also been determined.

The statement in Table 2 shows the plot arrangement together with the kinds and amounts of fertilizers applied annually during the last 5 years, the same periods for which yields are given in Tables 3 and 4.

TABLE 2.—FERTILIZERS APPLIED TO BRETON PLOT, 1940-44

Plot	Fertilizer	Average annual application, lb.				
		Fertilizers	Elements			
			N	P	K	S
1	None	—	—	—	—	—
2	*Manure	7 tons +	70	14	56	14
3	Complete {16-20 amm. phos.	58				
	Complete {K_2SO_4	33	9	5	13	15
4	Ammonium sulphate	59	12	—	—	14
5	None	—	—	—	—	—
6	*Lime	325	—	—	—	—
7	{*Lime	325				
	{Triple super	62	—	10	—	2
8	Triple super	62	—	10	—	2
9	{*Manure}{Amm. phos. 16-20}	{7 tons + 57}	79	19	56	22
10	16-20, amm. phos.	57	9	5	—	8
11	None	—	—	—	—	—
12	Roadway, permanent hay					
13	None	—	—	—	—	—
14	11-48, amm. phos.	57	6	12	—	1
15	2-20, super phos.	92	2	8	—	8
16	0-20, super phos.	84	—	7	—	7
17	*Bone, phos.	257	10	25	—	.3
18	None	—	—	—	—	—
19	Amm. nitrate	56	19	—	—	—
20	{Amm. nitrate	56				
	{*Gypsum	127	19	—	—	23
21	*Gypsum	127	—	—	—	23
22	None	—	—	—	—	—
23	Sod. sulphate	105	—	—	—	20
24	Pot. sulphate	77	—	—	—	15
25	{Pot. sulphate	83				
	{Amm. sulphate	60	12	—	33	31
26	None	—	—	—	—	—

* Most of the fertilizers are applied annually in a separate operation with the fertilizer attachment but not when the seed is being sown. However, manure, lime, bone and gypsum are applied at 3 to 5 times the above rates, but only at 3 to 5 year intervals.

During the earlier years the rates of fertilizers application were higher than indicated in Table 2, but as an average for the entire 15-year period the average annual rates were about 15% higher than for the the last 5-year period (1940-44).

When considering the yields in Table 3, it should be kept in mind that for Series E (continuous wheat) two years are required to produce each crop and that each crop has actually been fertilized during the fallow year and again during the crop year. Thus each plot in Series E receives the same amount of fertilizer as the corresponding plots in the other (rotation) series, but each half of Series E produces wheat only 50% of the time whereas some crop occupies the soil for the entire time in the rotation series.

We might be justified in dividing the yields shown for Series E by two before making direct comparison with the yields of wheat obtained when this crop was produced the first year after clovers.

The yields reported in Tables 3 and 4 are from seven series, each containing 25 plots. Eighteen plots in each series receives fertilizers of various kinds and amounts (see Table 2).

In the majority of cases (97%) the fertilizers have given increases in yields. Of the 126 fertilized plots only 4 show a minus sign and 3 of these are on Series E (continuous wheat). However, a number of the fertilizers have not proved to be efficient for these wooded soils and it is doubtful if such fertilizers as lime, triple super phosphate, bone, ammonium nitrate, will find an immediate general demand. From the standpoint of costs and efficiency for all crops, such fertilizers as ammonium sulphate, ammonium phosphate (16-20), single super phosphate and manure have given very good returns. Ammonium phosphate (16-20) supplemented with either potassium sulphate or manure has given the best all round results but the farmer cannot produce as much manure as we applied. Some of the other sulphur containing fertilizers were good for the legume hays but not so effective for the non-legumes. Most of them are fairly cheap but often they are difficult to apply.

TABLE 3.—AVERAGE GRAIN YIELDS AND INCREASES FROM THE BRETON EXPERIMENTAL PLOTS FOR THE 5-YEAR PERIOD 1940-44, INCLUSIVE

Plot	Fertilizer	Continuous wheat after fallow Ser. E, 5 yr.		(1) Wheat after clover 5 yr.		(2) Oats—2nd crop 4 yr.		(3) Barley—3rd crop 5 yr.	
		Yield	Increase*	Yield	Increase	Yield	Increase	Yield	Increase
1	None	17.1	—	12.9	—	25.8	—	13.0	—
2	M	29.2	12.7	32.8	19.0	58.0	30.7	25.1	12.6
3	16-20 + K_2SO_4	24.5	8.6	35.2	20.5	77.6	48.8	27.0	15.0
4	Amm. sul.	22.8	7.5	36.5	20.9	66.5	36.2	24.1	12.6
5	None	14.6	—	16.6	—	31.8	—	11.0	—
6	Lime	19.0	3.7	16.9	0.0	36.7	3.4	14.5	2.7
7	L-triple	21.4	5.3	27.2	10.0	46.3	11.5	20.0	7.3
8	Triple	17.1	0.3	25.3	7.8	45.4	9.1	16.8	3.3
9	M + 16-20	35.5	17.9	41.4	23.6	84.9	47.1	36.6	22.2
10	16-20	26.0	8.6	32.9	14.9	70.0	30.7	28.0	12.8
11	None	19.1	—	18.3	—	40.9	—	16.2	—
13	None	32.9	—	25.8	—	50.5	—	20.7	—
14	11-48	38.0	5.3	32.5	7.3	71.8	21.9	27.2	5.1
15	2-20	36.4	3.9	38.3	13.7	59.3	10.0	26.7	3.2
16	0-20	41.4	8.8	40.6	16.5	70.3	21.6	36.6	11.7
17	Bone	37.7	5.6	30.0	6.3	61.3	13.2	27.2	0.8
18	None	31.8	—	23.1	—	47.6	—	27.8	—
19	Am. nitrate	36.3	3.0	26.4	1.0	56.1	9.6	27.9	0.7
20	Am. nitrate + gypsum	36.0	1.3	38.4	10.7	68.6	23.5	33.9	7.2
21	Gypsum	33.2	−3.1	39.4	9.3	51.8	8.0	32.5	6.6
22	None	37.7	—	32.5	—	42.6	—	25.3	—
23	Sod. sul.	34.9	−1.9	40.6	9.1	62.0	18.6	26.9	1.5
24	Pot. sul.	33.7	−2.1	42.4	11.8	56.2	12.0	27.2	1.5
25	Pot. sul + am. sul.	37.2	2.3	42.8	13.2	69.6	24.5	31.3	5.3
26	None	33.9	—	28.7	—	46.0	—	26.1	—

* Increase calculated by using sliding scale from check yields.

The Breton experiments leave many questions that are not answered:

(a) What is the best way to produce legume seeds?
(b) What is the best legume to be grown?
(c) What is the best cereal to be grown?
(d) What is the best mixture for hay as pasture?

They do supply the answers to many questions, such as:

(1) Can satisfactory yields be produced every year?
(2) Can the weeds be sufficiently controlled so as to almost eliminate the fallow practice?
(3) What fertilizers and what rates are necessary?
(4) Can high quality crops be produced?
(5) Does proper management of these soils required the grain system or the livestock system of farming?

TABLE 4.—AVERAGE HAY YIELDS AND INCREASES FROM THE BRETON EXPERIMENTAL PLOTS FOR THE 5-YEAR PERIOD 1940-44, INCLUSIVE

Plot	Fertilizer	Clover, Average of 2 Series, 5 years		Alfalfa, 6 years	
		Yields, lb.	Increase*	Yields, lb.	Increase
1	None	806	—	900	—
2	M	2192	1380	1372	402
3	16-20 + K_2O_4	5761	4943	5020	4070
4	Amm. sul.	5057	4223	4915	3985
5	None	831	—	910	—
6	Lime	1049	187	2066	1147
7	Lime + Triple	2375	1482	2352	1424
8	Triple	2185	1361	2110	1173
9	M + 16-20	6328	5373	5116	4170
10	16-20	6111	5121	5374	4419
11	None	1016	—	963	—
13	None	1000	—	1045	—
14	11-48	2675	1611	2379	1132
15	2-20	5649	4521	5026	3577
16	0-20	5362	4170	4520	2869
17	Bone	1914	658	2884	1031
18	None	1321	—	2054	—
19	Amm. nitrate	1551	−145	2161	37
20	Amm. nitrate + gypsum	4968	2897	5473	3279
21	Gypsum	4882	2436	5451	3191
22	None	2823	—	2331	—
23	Sod. sul.	4955	2144	5123	2811
24	Pot. sul.	4747	1748	5626	3339
25	Pot sul + amm. sul.	4742	1955	5473	3211
26	None	2775	—	2237	—

* Increase calculated by using sliding scale from check yields.

From Tables 3 and 4 the following facts are evident.

Legumes must constitute a fair proportion of the cropped area of the wooded soils (not less than 40 to 50%). This means livestock to provide a home market for pasture and hay crops.

Where required, proper fertilizers must be applied. These are more important for the legumes than for the grains or grasses.

Annual applications of from 40 to 60 lb. of such fertilizers as ammonium sulphate or ammonium phosphate (16-20) or the equivalent of some other satisfactory fertilizer such as single super phosphate (2-19) at 60 to 90 lb. should be adequate.

The greatest possible use should be made of all farm manure.

When the above practices are followed it should be possible to produce satisfactory yields of all crops common to the district. This is indicated by our yields of $2\frac{1}{2}$ to 3 tons of hay, 35 to 40 bu. of wheat, 60 to 80 bu. of oats, 25 to 35 bu. of barley.

Weeds can generally be controlled without the use of fallow, provided clovers and hay occupy the ground for two or more consecutive years and provided annual grain crops do not succeed each other for more than two or three consecutive years. For the control of certain of the perennial weeds it may be necessary to resort to the fallow.

The summary shown in Table 5 gives a general idea of the quality of wheat produced on the wooded soils. Data are reported for protein content, loaf volume, and acre yields from the rotation series and from the continuous wheat series prior to 1942.

The yield data are necessarily different from results shown in Table 3 since a different series of years are averaged. It is seen that as an average of all plots (fertilized and checks) the wheat following clovers has out-yielded the continuous wheat by 10.8 bu. This is the average value of clovers as indicated by increased wheat yields. The clovers on the un-fertilized plots gave only 1.5 bu. increase whereas on some of the fertilized plots the increases ranged from approximately 10 to 17.5 bu.

In some of the co-operative experiments (not reported here) the protein content of wheat was as low as 7%. Most of the wheat grown by farmers on these wooded soils has protein contents varying from 7 to 10% and in general it is not grown following clovers. The wheat following clovers (Table 5) averages 13.2% protein while that from Series E averaged only 10.3%. The cropping practice (clovers in rotation) has had more effect upon the protein content than has the application of fertilizers. Wheat of high milling quality was not produced even when grown after clovers (average protein 13.2). This is shown by the data for loaf volume. The fact that some of the fertilizers increased the loaf volume (especially after clovers) does not mean that any of the plots yielded satisfactory milling wheat. Wheat, if grown on these soils, should be used as feed for livestock and should not be permitted to compete with high quality Canadian wheats.

Hays, oats, barley, flax of satisfactory quality can be produced. Grains should be largely fed to livestock on the farms in order to supplement the fodder consumed by livestock thus producing finished livestock and at the same time providing the greatest amount of farm manure. Barley of excellent malting quality can be produced. Certain of the legume seeds can be satisfactorily produced.

TABLE 5.—COMPARISON OF PROTEIN CONTENT, LOAF VOLUME AND YIELDS BETWEEN WHEAT GROWN AFTER CLOVERS AND WHEAT GROWN CONTINUOUSLY AT BRETON (PREVIOUS TO 1942)

——	Checks	Manure	16–20 + K_2SO_4	Amm. sulphate	Lime	Lime + Triple super phosphate	Triple super phosphate	Manure + 16–20	16–20	Average—All plots
Protein content of wheat (at 13.5% moisture)										
Wheat after clovers Average 12 years	13.4	12.2	12.6	13.8	13.6	12.9	13.1	13.0	13.6	13.2
Wheat continuous (Series E) Average 9 years	10.3	10.3	9.9	10.2	10.2	10.1	10.1	10.9	10.3	10.3
Rotation—Series E	3.1	1.9	2.7	3.6	3.4	2.8	3.0	2.1	3.3	2.9
Loaf volume cc. (baking tests)*										
Wheat after clovers Average 7 years	583	597	690	740	577	603	593	676	757	646
Wheat continuous (Series E) Average 5 years	516	516	519	566	496	517	481	610	563	532
Rotation—Series E	67	81	171	174	81	86	112	66	194	114
Wheat yields bu. per acre										
Wheat after clovers Average 12 years	14.5	25.1	33.5	29.3	17.9	23.4	21.7	34.5	32.1	25.8
Wheat continuous (Series E) Average 12 years	12.0	15.5	16.0	16.1	12.8	14.0	12.4	19.5	16.9	15.0
Rotation—Series E	1.5	9.6	17.5	13.2	5.1	9.4	9.3	15.0	15.2	10.8

* Baking data by Department of Field Crops.

* Baking data by Department of Field Crops.

The most urgent immediate problem retarding the development of the wooded soils is the cost of clearing and preparing the land for crops (5).

In order to maintain satisfactory yield levels it is necessary to follow mixed farming practices and include a good proportion of legumes.

Before the farmers on these wooded soils can generally become prosperous, adequate markets for livestock and livestock products at satisfactory price levels will have to be available.

Any extensive future settlement must, of necessity, be confined to the wooded soil area. This fact concerns every province and every citizen of Canada and will have a direct influence upon both our domestic and foreign markets. Immediate future settlement of some of these wooded soils must be considered in the rehabilitation scheme for many of the returned men from our armed forces.

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